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16. ABSTRACT

The framework for this document is based on scientific issues identified by EPA's Research Committees composed of representatives of the Office of Research and Development (ORD), Agency Program (regulatory) Offices and the Regions. One of the major issues is the development and evaluation of research on the impact and mitigation of acid deposition. Hazardous waste research is also a high priority. Other issues include biotechnology, reproductive toxicology and exposure assessment. A significant component of ORD's activities is devoted to the shorter-term resolution of technical issues identified by EPA's regulatory offices, including technical support and assistance. ORD also conducts oversight roles in quality assurance. In cooperation with Program Offices, ORD has been given the management responsibility for ensuring the consistency and technical competence of the risk assessment program, and managing new intra-Agency risk assessment workgroups for: carcinogenicity; mutagenicity; developmental toxicity; systemic effects; assessment of chemical mixtures; and exposure assessment.

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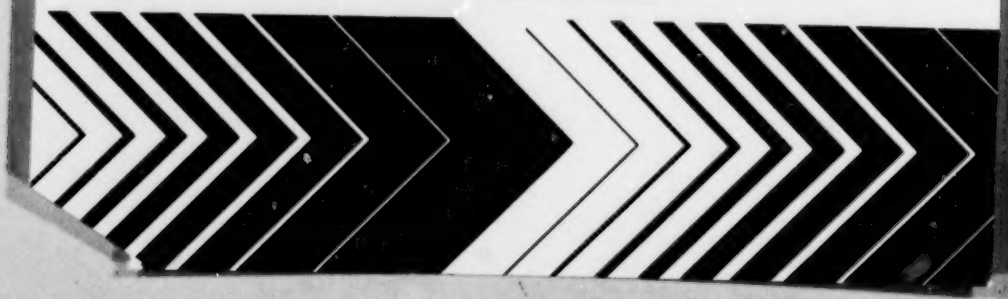

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Introduction

The primary goal of the U.S. Environmental Protection Agency is the reduction of risks to public health and to the environment. Within this context, the Office of Research and Development (ORD) provides scientific information necessary to determine the extent of these risks and to develop and evaluate technology options to reduce, eliminate or prevent them. As part of this process ORD must anticipate the scientific questions that will arise so that the appropriate data may be obtained and evaluated for the regulatory decision-making process. *The Long-Range Research Agenda* is a document prepared by ORD describing those future research needs for the period 1986-1991.

The framework for this document is a series of scientific issues identified by EPA's five topical Research Committees: Water, Air and Radiation, Hazardous Wastes, Multimedia Energy (including acid deposition), and Pesticides and Toxics. These committees, composed of representatives of ORD, Agency Program (regulatory) Offices and the Regions, are jointly chaired by senior managers from ORD and the appropriate Program Office. The critical scientific issues for each committee were delineated in a joint strategy document by the Assistant Administrators of ORD and the appropriate Program Office. Thus, these issues reflect the perspectives of both the regulatory and research offices of EPA on where the scientific uncertainties lie and how the Agency might reduce those uncertainties in the 1986-1991 time period. Research plans for the 1987-1991 time period are subject to changes reflecting funding levels, competing Agency priorities and new or modified legislation.

The issues in the *Agenda* are organized by research committees which provide integrated planning within a media. This integration and coordination includes those investigations conducted by the Program Offices. While some studies are undertaken by the Program Offices, research is conducted through the offices of ORD which are generally organized according to broad disciplines and which provide information for all the committees. For example, while each of the committees has various issues dealing with human health, the Office of Health Research is responsible for managing human health research across all committees. The integration of the overall research program is, thus, a matrix of topically oriented research committees and discipline-oriented offices.

One of the major issues facing ORD is the development and evaluation of research on the impact and mitigation of acid deposition. While research in this area is a multi-agency responsibility, EPA has the major lead in aquatic effects, control technology and assessment. EPA also contributes

significantly to the other areas of the research program such as terrestrial effects and materials damage. Studies on acid deposition constitute the major portion of the multimedia and energy research efforts and are discussed in detail in that chapter.

Hazardous waste research is also a high priority. As a result of the recent amendments to the Resource Conservation and Recovery Act (RCRA), some sections of the hazardous waste research program will increase in priority. The major increases will occur in research on underground storage tanks, alternative treatment process, and conventional landfills (Subtitle D facilities).

Because of the cross-cutting nature of some health and environmental problems, planning for some research areas falls into the domain of more than one research committee. For these, ORD has proposed, as part of the long-term planning process, several initiatives that address issues requiring multi-disciplinary inputs or coordination between several research committees. Included among these issues are three topics which will be receiving increased emphasis over the next five years: biotechnology, reproductive toxicology and exposure assessment. While they are not new areas for EPA research, they have become significantly more important to the conduct of the Agency's regulatory mission.

ORD's biotechnology efforts have the goal of providing the information necessary to protect the environment from risks associated with bioengineered organisms. Included are methods to monitor these organisms, to determine potential health or ecological effects, to control or contain releases, and to develop risk assessments. The increased effort in reproductive toxicology is needed to rectify the paucity of information on the effects of chemicals on the human reproductive system. This research will emphasize test method development, extrapolation of effects from animals to man, development of early biological indicators and risk assessments. Increased research in exposure assessment will provide the improved understanding of human and environmental exposure to pollutants needed to increase the accuracy of risk assessments.

EPA's research is carried out in the ORD laboratories as well as through contracts, cooperative agreements and interagency agreements with organizations outside EPA. ORD also has an Exploratory Research Program to support more basic and fundamental environmental research. This research is carried out through the Research Grants and Centers programs and is discussed in the final chapter.

While the topics explored in this year's *Agenda* represent EPA's judgement of the highest priorities facing the research community through the remainder of the decade, they do not include all of the ongoing research related to EPA's mission. In addition, a significant component of ORD's activities is devoted to the

shorter-term resolution of technical issues identified by EPA's regulatory offices, including technical support and assistance. ORD also conducts oversight roles in quality assurance and management of risk assessment activities. These two programs are briefly described as follows.

Quality Assurance Oversight Activities. Quality assurance (QA) is a multi-faceted, interdisciplinary program that affects all Agency-supported activities involving environmental data collection. The goal of QA is to ensure that the data produced by these activities are of known and documented quality, and meet the requirements established by the responsible office or laboratory. Quality assurance is central to the scientific integrity of every environmental data base developed by (or for) EPA and hence is vital to the confidence with which Agency managers can make policy and regulatory decisions.

The Office of Research and Development is the focal point for quality assurance within EPA, with responsibility to develop QA policy and guidance, coordinate and direct QA program implementation, and evaluate QA activities Agency-wide. Because the quality required for collected data is a function of the use to be made of that data, ORD assists Program Offices, Regional Offices and laboratories in their development of appropriate data quality objectives.

Policy and direction are provided through guidance documents and through administrative and technical meetings on appropriate procedures and methods. ORD, with the help of specific Program and Regional Offices, also prepares technical materials. In the near term, ORD is concentrating on institutionalizing the data quality objective process throughout the Agency, obtaining resources for adequate QA at the Regional Office level, developing specific guidance on performing audits and compiling key information on routinely used measurement methods.

ORD also reviews all Program and Regional Office and laboratory quality assurance plans to determine programmatic and resource commitments, compliance with established guidelines and the likelihood of meeting goals. Audits or reviews of audits are conducted to assess the degree of implementation and overall effectiveness as well as to identify problem areas and appropriate corrective actions.

Risk Assessment Management. Nearly every Program Office in EPA uses risk assessment in its regulatory or decision-making processes. In the course of a year, about three thousand documents related to "risk assessment" are produced throughout EPA. However, the Agency's assessment activities differ in the nature, technical approach and amount of peer review that they undergo before being used in the decision-making process.

In cooperation with the Program Offices, ORD has been given the management responsibility for development of risk assessment procedures and for ensuring the consistency and technical

competence of the overall risk assessment program. ORD manages a series of new intra-Agency workgroups which have developed or will be developing guidelines for risk assessment for six primary topics: carcinogenicity; mutagenicity; developmental toxicity; systemic effects; assessment of chemical mixtures; and exposure assessment. The guidelines are being reviewed by EPA working groups, recognized experts outside the Agency, EPA's independent Science Advisory Board and other interested parties.

A Risk Assessment Forum has also been established to develop consensus on intra-Agency scientific risk assessment questions. The Forum embodies the collective expertise within the Agency—the senior scientists/managers responsible for risk assessment from each of the Program Offices as well as representatives from the Office of General Counsel and the Office of Policy, Planning and Evaluation—and will meet to review risk assessments upon the request of the Administrator, Deputy Administrator, Assistant Administrators, or Regional Administrators. The Forum will provide a mechanism for interchange on science issues in risk assessment and advise the Administrator and Deputy Administrator on precedent-setting cases and important risk assessment questions.

Water

Water research provides the knowledge and methods required to protect our Nation's freshwater and marine environments, to ensure the continued safety of our drinking water supplies, and to implement the most cost-effective wastewater treatment technologies. Demands on water supplies are increasing while chemical contamination from toxic wastes and waterborne diseases are posing major threats to some localities. Traditional methods and strategies to measure and control pollution effects, especially from organic chemicals, may no longer provide the level of assurance demanded by the public. In order to meet the challenges of increasingly complex contaminants in water, research must develop effective approaches to assess a growing number of potentially harmful mixtures of organic, toxic and chlorinated organic compounds. Water management is becoming more complicated, and regulators in both the federal and state sectors require greater scientific certainty as a basis for their decisions.

In this context, EPA's health effects research is important to the development of both drinking water and ambient water quality regulations. The engineering research program's evaluation, development and transfer of innovative treatment technologies to municipalities, industry and private landowners assists in the implementation of cost-effective alternatives. EPA is also accelerating its research into the toxic impacts to fish, wildlife and their ecological systems. Finally, the necessity for credible research and monitoring data is a cross-cutting issue of significance to the entire research program.

EPA's water research programs will continue to provide support to the Agency in the following areas: developing revised and new drinking water Maximum Contaminant Levels and Health Advisories; developing Criteria Documents and the scientific underpinnings of ambient water-quality regulatory policies; assisting the Regions and states to meet the burgeoning demand for toxicity-based National Pollutant Discharge Elimination System (NPDES) permits; and providing technical support to the municipal wastewater construction program in pretreatment, sludge, infiltration/inflow and other areas.

The ten topics described in this report represent the principal concerns in the water research area. However, they do not include all of the ongoing research related to EPA's water protection mission.

Major Research Issues

Water-Quality and Toxicity-Based Approaches

What information and tools are needed to support implementation of state water quality standards and toxicity-based permits? How can research results in these areas be most effectively transferred to EPA Regions and the states?

The Clean Water Act (CWA) recognizes two types of regulatory requirements to restore and maintain the quality of the Nation's waters. Technology-based guidelines set uniform national requirements for discharges by industries and sewage treatment facilities. Water quality-based standards define the uses to be made of water such as drinking water supply or recreation and, subsequently, establish a site-specific criteria protective of that use.

In 1984 EPA issued a new policy for National Pollutant Discharge Elimination System (NPDES) permits requiring a balanced consideration of physical, chemical, biological and microbiological factors. To support permit development, biological toxicity-testing will provide quick, inexpensive screening for potentially harmful substances in complex effluents. EPA's research program will continue to develop rapid assessment procedures to expedite toxicity-based permitting.

Despite significant reductions in point-source pollutant levels as a result of the implementation of technology-based discharge limits, there are still water bodies which do not meet water quality standards. Moreover, there are increasingly important water quality problems caused by toxic substances, non-point sources, or other factors such as reduced flow. EPA's research into this area integrates seven components:

Water Body Assessment and Monitoring. Extensive evaluation of biological methods for monitoring aquatic life and pathogens of concern for human health will be necessary to standardize use-attainability protocols for site-specific water quality surveys. Additional research will focus on computerized biological data management systems, modifying and standardizing analytical methods for organic and inorganic chemicals and metals, and determining the method's accuracy, precision and detection limits for the chemicals of interest.

Use Attainability. In order to ensure that water quality goals are ecologically attainable, an orderly process is used to classify possible uses and levels of use, determine attainability, set ecological requirements for the use, ensure that these requirements are met, and, finally, monitor results. The use designation (e.g., drinking water source, sport fishery, etc.) reflects the human use of water bodies. This use designation defines the desirable goals for the water body. Research will develop methods to assess ecological potential. An ecoregional approach

will be used to predict general levels of attainability and to predict methods of determining wildlife potential based on physical habitat and other features.

Complex-Effluent-Toxicity Testing. Most pollutant sources produce complex mixtures of chemical constituents. Aquatic research on complex mixtures will be designed to develop short-term toxicity tests and to identify significant relationships between ambient toxicity and biological community impairment. Other research in this area will support the development of methods to predict toxicity persistence as well as assessment of the precision of acute and short-term toxicity tests. Health effects research will attempt to apply existing health bioassays for use in evaluating effluents for human health risks. The health concerns are chemicals that cause cancer, genetic changes in cells and chronic toxicity. The bioassays and the design of the tier testing protocols will be developed through a peer review workshop, followed by field validation of the protocols.

Wasteload Allocation. The wasteload allocation (WLA) process is the basis for permit limitations for individual dischargers. Margins of safety, distribution of treatment responsibility among dischargers and nonpoint-source contributions are considered. Many water quality models are available, and efforts are underway to make these models more useful to the states. This effort will include models of toxic wasteloads as well as conventional pollutants. ORD will participate in developing toxicity-based permits at some demonstration sites and will gather information on single-constituent and complex wastes in ambient concentrations. In addition, the research program will develop and compile data bases of environmental-process rate coefficients, analytical techniques for organic and inorganic chemicals and provide current aquatic resource inventories to identify the extent and causes of water quality degradation and the results of controls to date.

Mixing Zones. Forty-eight states allow mixing zones where discharged pollutants may exceed long-term standards. EPA will collect data on the exposures to various toxic pollutants that organisms can tolerate within these zones.

Toxic Levels in Sediments. Many heavy metals and organic chemicals adsorb on suspended sediment. Release of these toxicants to the water can occur, increasing exposure factors and bioaccumulation throughout the food chain. EPA will seek to develop sediment criteria for such toxic compounds.

EPA's research support to toxic discharge permitting will focus on representative permit demonstrations and the development of microcomputer programs for on-site data analysis and evaluation of toxic dischargers.

Great Lakes Research

How can we understand and eliminate the environmental contamination problems identified in the Great Lakes?

The Great Lakes, their connecting channels and tributaries constitute a dynamic and complex freshwater ecosystem unparalleled in the world. During the last two decades, significant progress has been made in reducing the amount of conventional waterborne pollutants entering the Great Lakes. However, increased use of industrial chemicals and their presence in the Great Lakes have raised public concerns about toxic pollutants, particularly persistent organics. Many of the problems and approaches discussed in other parts of this chapter also pertain to the Great Lakes. Specific approaches may differ, however, due to the large size and economic and recreational value of these lakes.

EPA's strategy is to develop an early-warning mechanism for the migration of contaminants from harbors and nearshore areas into the ecologically important areas of the Lakes, and to develop protocols for assessing the contaminants' impacts on the ecosystem. However, because of the complexity of many persistent organics, it is difficult to predict the potential adverse impact of these chemicals on organisms in the food chain, including humans. EPA will focus on determining biological uptake of selected dioxins, which have been reported in high concentrations in fish. The inadequate toxicity data on organic compounds found in freshwater systems restricts our ability to establish effluent limits. EPA will determine the acute and chronic toxicities of organics such as dioxins at environmental concentrations.

Analytical methods for many of the existing organic compounds are inadequate to detect environmental concentrations at trace levels. EPA will develop accurate and sensitive methods for determining the contaminant load which is chemically suited for uptake by the biota, the contaminants which tend to build up within organism tissues, toxic levels, and fates and effects. Existing mathematical models have limited capabilities to relate pollutant exposure levels to the sources of organic compounds. In order to make defensible use of predictive models in determining biological availability and environmental effects of toxic organics, EPA will integrate models of fate and transport with models of food chain uptake.

Non-point source pollution is also a problem in parts of the Great Lakes. Research will evaluate the cost-effectiveness of innovative and alternative Best Management Practices (BMPs) for controlling problems such as siltation from agriculture, mining and urban runoff.

Estuary Protection Research

What information and tools are needed to protect estuaries from excessive nutrients and toxic chemical contamination?

Estuaries are valuable ecological systems, both directly as local fisheries and recreation resources, and indirectly as nursery

areas for oceanic fisheries. Estuaries often lie at or very near the center of many industrial activities, including those involved in the production, transportation, consumption and release of toxic chemicals. In addition, rivers, lakes, and reservoirs contribute pollutants such as contaminated sediments, excessive nutrients, agricultural chemicals and other toxic materials. Water quality managers and planners in the states and interstate commissions are dependent upon scientific information that supports regulatory alternatives to protect estuarine waters for multiple uses such as cooling water supply, recreation, fishing and maintenance of fish stocks, and industry. The basic scientific uncertainties involve the quantification of pollutant loads, their transport and fate, and their cumulative effects on the resources. EPA is currently involved with the states, the National Oceanic and Atmospheric Administration of the Department of Commerce, the Department of the Interior and the Army Corps of Engineers in five major estuarine studies: the Chesapeake Bay; Long Island Sound; Buzzards Bay, Massachussetts; Narragansett Bay, Rhode Island; and Puget Sound, Washington. The Agency is also concerned with other critical estuarine areas, such as those in the South Atlantic, Gulf of Mexico and the Pacific coast.

Excessive Nutrients. A number of questions remain to be answered concerning the dynamics and fate of nutrient chemicals deposited in estuaries. EPA's research is concentrating on the relative importance of point sources and non-point sources of nutrients, the quantitative relationship between nutrient supply and anoxia under different hydrological conditions, the effectiveness of phosphorous-control strategies, ecological indicators of site-specific water quality criteria, the role of sediments as sources and sinks for nutrients, the ecological consequences of treated wastewater that is deficient in silica, and evaluation of cost-effective methods to monitor various estuaries.

Toxic Chemicals. The questions surrounding the physical, chemical and biological properties of toxic substances in estuaries are similar to those involving toxic materials in other aquatic systems. Models describing environmental processes must be better documented and field tested. EPA is also evaluating weaknesses in analytical methods for sediment-bound toxics, the role of suspended sediments on bioavailability and bioaccumulation of toxics, and the extent to which complex effluent testing may be necessary in estuaries to establish reliable water and sediment quality criteria.

Non-Point Source Controls. An understanding of the site-specific impact of non-point source pollution is vital to the protection of estuarine areas. Research will improve the predictive capabilities for the runoff of nutrients and toxic substances and the verification of simulation models for individual estuaries. Existing models may need to be modified to include additional impacts such as the infiltration and transport of toxics to the ground water. Best Management

Practices may also require evaluation as to their site-specific cost-effectiveness.

Wastewater Treatment Technology

What information and tools are needed to improve the reliability of the performance and the cost-effective construction or renovation of municipal wastewater facilities?

The costs of construction and operation of conventional secondary and advanced wastewater treatment facilities represent major public sector expenditures. To assure effective and least-cost solutions for control of municipal discharges, research must resolve a number of technological issues associated with defining the effectiveness and costs of water quality treatment and management practices. EPA provides technical evaluations of the costs, performance and effluent variabilities of various new innovative and alternative technologies at a scale sufficient to reduce economic risks to the designers and the utilities. For existing facilities, emphasis will be on plant upgrading as a cost-effective alternative to new construction. Examples of such alternatives include converting coarse-bubble aeration to fine-bubble aeration to increase oxygen transfer, increasing aeration surface areas, using high-biomass reactors, and the selective application of biotechnology.

Research support is also required to address the problem of combined wastewater and stormwater sewer overflows. The goal of this research is to provide reliable information to those state and local regulators responsible for the achievement of water quality standards through facility planning, system design and permit issuance. A particularly strong need for research and technology information exists for small wastewater treatment systems.

Innovative/Alternative Technologies. EPA's wastewater treatment technology research program will develop data on the costs and performance for a range of innovative and alternative technologies. High priority areas include the identification of low-cost methods to improve existing facilities for smaller communities, and the assessment of innovative and alternative technologies. The program will also evaluate new design concepts to achieve compliance with state discharge permits such as innovative nutrient removal processes for Chesapeake Bay.

Toxic Pollutants. Cost/performance information will be developed on engineering options for methods of treating and eliminating toxic pollutants from industrial waste sources. This will include evaluations of the role of municipal treatment plants and their ability to remove toxic pollutants in order to evaluate what can be treated centrally and what has to be required in industrial pretreatment. The engineering data base will be updated to help states implement a national pretreatment program. A recent workshop identified needed research to

interpret the significance of mutagenic contaminants found in treatment plant effluents. Any significant mutagenic fraction must be identified and isolated so that specific treatment or pretreatment technologies may be designed to mitigate the presence of toxic chemicals in effluents.

Monitoring. ORD will continue to be responsible for quality assurance in wastewater monitoring. It will continue to assess the adequacy of analytical performance and report the results of its audits to the analyst, laboratory, state and region. The data from the 8,000 major NPDES dischargers will continue to be monitored and will serve as the basis for calibration and methods evaluation to support EPA's implementation of Section 304(h) of the Clean Water Act.

Ocean Disposal

What information and methods are needed to predict and control the environmental impacts of ocean disposal of municipal or industrial wastes?

The EPA is charged with regulating waste disposal activities in the marine environment. Among these activities are the dumping in the ocean of wastes such as dredged material, sewage sludge and industrial wastes; the incineration-at-sea of hazardous liquid wastes; and the disposal of municipal and industrial wastewater through ocean outfalls. An improved understanding of the ecological consequences of ocean disposal will be needed to guide future public policy, to satisfy international marine treaties and, where possible, to protect and enhance coastal fisheries resources. A major need is to gather facts on the relationship between disposal costs and protection of marine life. EPA's research is carried out in collaboration with the National Oceanic and Atmospheric Administration and the U.S. Army Corps of Engineers.

Key questions concerning ocean dumping and incineration-at-sea involve the procedures to be used in dumpsite selection, the assessment methods to be used in evaluating the impact of ocean disposal and the procedures necessary to monitor dumpsites for long-term impacts and to validate predictions made about potential impacts. For effluents discharged from publicly owned facilities through ocean outfalls, the CWA requires secondary treatment. However, partial waivers are allowed in selected cases, and EPA must have a scientific basis for determining when a modification of the secondary treatment requirement may be allowed and what effluent limitations would be imposed for each special case. To support its ocean dumping and outfall permit programs, and to assess the water impacts of incineration-at-sea, EPA's research will focus on three major activities:

Hazard Assessment. A hazard assessment procedure will be developed to provide the data and interpretation necessary to define the probability of harm to the marine environment. This

information is necessary to determine the relative safety of ocean disposal and to provide a comparison for various disposal strategies for future ocean policies.

Bioaccumulation. A thermodynamic model for predicting the maximum probable bioaccumulation from sediments and sewage sludge will be developed and validated. Research on the biological and ecological significance of tissue residues will include the development of a conceptual model and a research strategy to include the pharmacological, toxicological and structure/activity principles to determine the link between residues and biological effects.

Monitoring. Research will develop a monitoring strategy for coastal and deepwater applications that will identify techniques for measuring the physical, chemical and biological characteristics of a disposal site. The objective of this effort is to develop, field test and evaluate integrated monitoring approaches to satisfy monitoring needs required for the evaluation and renewal of marine disposal permits.

Sludge Disposal Management

What information is needed to develop and to assist the states in implementing sludge disposal regulations?

About eight million tons (dry weight) of sludge per year are produced from municipal wastewater treatment plants in the United States. The processing and disposal of this sludge accounts for about half the total operating costs of a typical sewage treatment plant. As a result of the large volume of sludge and the presence of potentially harmful constituents, municipalities are facing increased economic and public problems with current land and ocean disposal practices. Approaches to disposal are needed that will: (1) significantly reduce the volume of sludge; (2) destroy pathogens; (3) insure that toxic metals are not a problem; and (4) reduce toxic organic compounds. There is also a need to ensure that sludge disposal does not present a threat to groundwater. To support the new EPA regulations, research efforts will focus on sludge use criteria, procedures and requirements applicable to the regulatory process.

EPA will refine methods to assess sludge disposal options including research to determine ecosystem resiliency or stress resulting from disposal and to predict the human health effects from exposures to sludge.

Health Effects. EPA's research on potential human health effects of sludge disposal is concentrating on developing data on various chemical and bacteriological contaminants in sludge, and hazard indices for their effects associated with different exposure pathways. Further research will focus on processes to kill parasites and pathogens in sludges. Epidemiological studies have been initiated to evaluate health hazards from exposures to sludge where composted sludge is sold as fertilizer.

Results from these and other studies will provide data for determining the effects of various sludge treatment processes on mitigating disease.

Risk Assessment. Decisions on alternative means of sludge management require improved risk assessments. EPA will develop information on mitigating risks through sludge treatment or disposal options, and will produce guidelines for conducting health risk assessments of sludge disposal.

Engineering and Technology. A principal objective of EPA's sludge management research program involves determining the cost compared to performance of various engineering designs for treatment and disposal options. In evaluating new processes for improved sludge stabilization, volume reduction, energy recovery and land use, EPA will support pilot studies of innovative combinations of activated, anaerobic sludge digestion and wet-oxidation to determine efficiency, performance and cost. Another key area of research will establish the relationship of heavy metal and toxic organic compound levels in municipal wastewaters to the levels in sludge.

Drinking Water, Health Effects and Treatment Technologies

What health effects are caused by chemical and microbial contaminants found in drinking water, what are the risks associated with them, and what new technologies are needed to continue to assure the safety of drinking water?

The Safe Drinking Water Act requires EPA to establish drinking water regulations to protect human health and welfare. State and local governments, with the primary responsibility for providing safe drinking water, need help with the many potential problems related to drinking water quality. Pending revisions of the National Interim Primary Drinking Water Regulations will incorporate new standards for a variety of synthetic and volatile organic chemicals. EPA's drinking water research program will continue to provide support to the Office of Drinking Water and to the states in their implementation of safe drinking water programs.

Traditionally, drinking water standards for protecting human health have been developed on a single-chemical basis. However, as in other aspects of water research, methods are also needed to determine the toxicological activity of the aggregate of chemicals found in water through bioassays, and to determine the relative risks from the bioassay data. This approach would have direct application in assessing health risks of drinking water from any source, and would support reliable determination of risk from exposure to complex mixtures.

EPA's drinking water technology research program has two principal objectives: (1) provide engineering data necessary to support the development and revision of drinking water

regulations; and (2) provide engineering information and technological support to states, municipalities, EPA regions and utilities relative to drinking water regulations and compliance. The major technological gaps that may affect our ability to provide safe drinking water include: inadequate data on the relationship between treatment strategies and consequent deterioration of water quality within the distribution system; insufficient data on the factors causing deterioration of water quality within the distribution system itself; and problems with bringing small systems into compliance. Another area of concern is the impact of distribution system corrosion on drinking water quality and low-cost techniques to solve these problems.

Toxicity of Complex Mixtures in Drinking Water. EPA's research will concentrate on the development and application of bioassays to determine the health significance of complex mixtures of chemicals. This will lead to methods for developing drinking water standards based on the toxicological risks of the spectrum of chemicals in drinking water instead of on an individual-chemical basis, and would better define the risk to public health. Planned activities include sample-concentration procedures for preparing representative samples for toxicological evaluation of drinking water, development of a protocol and risk assessment methodology to estimate reproductive hazards and target-organ toxicity, and reporting on relative risks from potable water derived from various sources.

Toxicity of Single-Chemicals in Drinking Water. The need still exists to determine the health effects of specific chemicals that potentially contaminate water supplies at toxic levels. Studies will be conducted on specific chemicals to provide specific data to support regulatory and health advisory decisions. The individual chemicals will be selected based on potential or actual occurrence in drinking water supplies. Through these tests, the relationships between dose and response and the mechanisms through which toxicity is effected will provide valuable data to support the development of risk assessment and Maximum Contaminant Levels in drinking water. This approach complements a similar effort to use toxicity screening as a means of controlling effluents.

Disinfection By-Products. Trihalomethanes were the first recognized by-products of the chlorination of drinking water. It is now clear that a variety of other potentially carcinogenic and mutagenic chemicals, such as haloacetonitriles, halogenated aldehydes, ketones, and a number of as-yet unidentified by-products are produced by chlorination. The toxicity of the by-products of alternative disinfectants to chlorine are even less well understood. In addition to the by-products formed in drinking water, a variety of other substances are produced in the bodies of those who drink the water. Research will continue on improving treatment technologies including disinfection, microbe filtration, ion exchange, aeration, adsorption and reverse osmosis for the control of organic and radionuclide

chemicals, chlorinated organics and particulates. Laboratory, pilot and field studies will be conducted to define the interaction between treatment strategies and water quality deterioration in distribution systems. Research by EPA seeks to identify disinfection by-products, determine which of these chemicals possess toxicological properties, establish the dose/response relationships for these effects and, ultimately, establish the risk involved with alternative disinfectants.

Infectious Diseases. The classical public health problem in water has been the prevention of waterborne infectious disease. Research must take into account problems with pathogens such as *Legionella*, *Giardia* and Norwalk-like viruses while establishing the health impacts of various treatment and distribution processes. EPA's research is concentrating on developing methods for the isolation, identification and quantification of waterborne pathogens, determining the effects of changing disinfection practices on infectious disease occurrence, and developing a dose/response water quality indicator that correlates with disease.

Overall System Integrity. The persistence and potential regrowth of organisms in distribution systems are influenced by a variety of conditions that include physical and chemical characteristics of the water, system age, pipe materials and the availability of suitable sites for bacteria colonization. Laboratory and field studies will be conducted to evaluate the impact of changes in treatment and disinfection practices brought about by existing and new regulations. Investigations will also be carried out on other key factors that influence microbial regrowth, including nutrients, temperature and protective habitats such as sediment accumulations. In addition, theoretical, laboratory and field studies will be conducted to define the factors associated with distribution system repair and replacement criteria, including costs associated with the optimal renovation strategies.

Small System Compliance. Special attention is directed at the needs of small drinking water systems (under 10,000 persons) since this is where the bulk of drinking water compliance problems occur. Research is evaluating the cost and engineering feasibility of specific treatment techniques to remove or control problem organic and inorganic contaminants, trihalomethanes, microorganisms and particles. Several evaluations will be at pilot or full-scale. Laboratory-scale studies are being done to define variables that govern the effectiveness and efficiencies of treatment processes prior to large-scale evaluations.

Groundwater Protection

What information and methods are needed to improve the monitoring, prediction and reclamation of the problems caused by groundwater pollution?

Underground aquifers are a major source of water for drinking, irrigation and industrial development. However, in some

instances, these aquifers are threatened by poor waste-management and improper safeguards. The list of potential contaminant sources is large; among the most common are leaching from landfills, dumps and impoundments, mining and radioactive waste disposal sites, underground waste injection wells, petroleum development, saline recharge, excessive use of agricultural chemicals, and accidental spills.

The research base for assessing and predicting the impacts of groundwater pollution lags far behind that for surface-water sources. While we know reasonably well how a few organic chemicals behave in a few groundwater environments, a great deal remains to be accomplished to significantly bridge the data gaps, expand predictive capabilities, reduce costs and improve the accuracy of groundwater monitoring, and determine the feasibility of cleanup. The following discussion includes those aspects that are not addressed under other research programs.

Monitoring. Research will evaluate geophysical and geochemical methods for the detection and mapping of subsurface leachates and groundwater contaminant plumes. EPA's research objectives are to survey, develop, test and evaluate both surface-based and downhole instruments and methods which can be used for such monitoring and hydrogeologic investigations. EPA will also examine these methods for monitoring deep contaminant plumes associated with underground injection. Additional research will evaluate "indicator" parameters which may detect the presence of hazardous constituents in groundwater during active site operations and after site closure.

Prediction of Contaminant Concentrations. EPA's research will focus on the definition of the relationships between subsurface hydrogeological properties and pollutant transfer. This includes the determination of the chemical and microbiological contaminants susceptible to transformation, the physical and chemical components of dispersion, and the prediction of groundwater quality at a point of use.

Aquifer Restoration. *In situ* aquifer restoration refers to the cleanup of contaminated groundwater, while still in the aquifer, to a degree where the water will be restored to safe levels for use. This capability is in its infancy, and EPA's activities will emphasize compilation of existing information, developing methods for isolating contaminated plumes, and evaluating the feasibilities and cost-benefits of various mitigation techniques. EPA will also demonstrate selected technologies through limited field testing.

Monitoring Data Quality Assurance

To what extent can data collection and reduction methods be standardized to assure reliability, repeatability, intercomparability, and scientific credibility?

The goal of quality assurance is to ensure that data generated in monitoring and other measurement programs are technically

and scientifically defensible. At the heart of quality assurance are the methods used to collect and analyze samples. These methods must be developed and validated so their performance is acceptable to the regulated organizations and the independent scientific community. While sampling and analytical methods are available and deployed within the appropriate measurement programs, without standardization, sampling and analytical methods for water and wastewater monitoring will vary in unknown ways and with them will vary the quality of the data.

Many of the quality assurance (QA) activities are on-going, level-of-effort programs which are critical to EPA's water quality monitoring activities. The current QA program for water quality research includes conceiving, developing and providing the tools, guidelines and technical support to cost-effectively maintain the scientific credibility of the collected data. In this context, the QA program provides guidelines to establish acceptability of data of known quality and for sampling to determine representativeness of the data. A number of questions require additional investigation as the monitoring and measurement systems mature with changing demands for research support.

Repositories of Analytical Standards. EPA repositories of analytical standards play a critical role. Standards, developed by EPA for most of the pollutants used to define water quality, are made available on a voluntary basis to research, enforcement and compliance offices and to other water quality laboratories to provide an analytical reference point. The continued availability and use of these primary analytical standards is one of the most cost-effective ways to assure credibility and intercomparability of laboratory results.

Analytical Proficiency. The QA program conducts a variety of performance evaluations. Some of these are voluntary, such as the Water Pollution and Water Supply series in which participating laboratories are provided blind samples for analysis. Their results are statistically analyzed and poor performers are alerted to correct their performance. Other studies are conducted in direct support of the Program Offices, such as the Discharge Monitoring Report Quality Assurance program for the Office of Water Enforcement and the Laboratory Certification Program for the Office of Water Supply.

QA Guidelines. The quality assurance program for water is developing guidelines for facilitating quality control statistics and electronic transmission of data with automated techniques for real-time QA capabilities. Additional guidelines are being prepared for measurements of viruses, microbiological systems and larger organisms, and for QA in physical and chemical analytical laboratories.

Summary of Long-Term Trends

Most of the water research issues described in this chapter will continue into the next decade, with gradually changing degrees

of activity and emphasis. Improved analytical capabilities will continue to lower the detection limits of trace constituents in water, resulting in identification of greater numbers of potentially deleterious chemical contaminants. Coupled with more toxicological and epidemiological information, water quality managers will face increasingly difficult decisions involving the environmental significance of complex mixtures of pollutants.

A significant near-term issue includes the development of toxicant information for complex mixtures. The growing inventory of chlorinated organic contaminants in complicated combinations requires significant changes in the research strategies and technological methods used to assess them. Whole-sample evaluations such as matrix bioassays, biological indicators and chemical surrogates will play a larger role in the future. To remain responsive, EPA's water research program must simultaneously develop and validate new methods while applying them in regulatory situations.

The environmental water quality issues, including non-point source pollution, estuary protection, ocean disposal of wastes and the water quality-based approach, all reflect the emerging need to develop new tools to test and monitor ecological impairment, including toxic effects on aquatic species. Over the next decade, major strides will be made in establishing safe, or "no-effect" levels of toxic organic contaminants in sediments and water, and in methods to establish biological availability and bioaccumulation in tissues.

Many communities and landowners rely upon groundwater sources for drinking and irrigation. Questions regarding the quality of groundwater have been increasing in recent years. Consequently, the dynamics of groundwater and the residence times and fates of leached contaminants in these aquifers will be a major water resource issue for the remainder of the century. The coming decade will see the refinement of the capability to simulate and predict the impacts of contaminants on underground sources. Increased research will improve approximations of the behavior of contaminants in aquifers and the transport mechanisms of surface pollutants leached into the ground. The fates and effects of toxic compounds and anthropogenic radionuclides in ground water will not likely be adequately understood until well into the future.

In the wastewater treatment areas, no fundamental changes are foreseen. Improved engineering and the periodic emergence of innovative and alternative technologies will partially offset the rising costs associated with wastewater treatment. A major breakthrough in wastewater treatment, if there is one, may come from biological engineering, possibly by developing organisms which could be more effective in treating wastewater.

With the increasing complexity of the information base available to state and local water quality managers, technology information transfer will continue to be a fundamental component of

EPA's research program. While not, strictly speaking, a research issue, demands for current technology and data outside the federal scientific community will increase as water quality protection is transferred to the states. The coming decade will experience significant changes in information management, with much greater emphasis on microcomputer-based technologies for site-specific applications. EPA's research program is already developing and demonstrating this important new tool.

Finally, the demands on quality control of research and monitoring data will grow with the lowering of detection limits and the concomitant increase in new compounds. While the methods for quality assurance will not materially change, relying as they do on statistical analysis of the underlying technologies, the mechanisms whereby EPA implements its QA may change to reflect the costs of ensuring credibility and standardization. EPA believes that its QA programs in methods development and laboratory certification are vital components of its mission. However, the future may bring about a transfer of its program of providing reference samples to the private sector, with the costs directly borne by the permittees and other analytical users.

Air and Radiation

Under the Clean Air Act (CAA), as amended in 1977, EPA is responsible for setting ambient air quality standards to protect the public health (primary standards) and welfare (secondary standards) from air pollutants emitted from both stationary and mobile sources. National Ambient Air Quality Standards (NAAQS) have been set for six "criteria" pollutants: ozone (O_3); carbon monoxide (CO); particulate matter (PM); sulfur dioxide (SO_2); nitrogen dioxide (NO_2); and lead (Pb). As required by law, these standards must be reviewed every five years and revised if necessary. Compliance with these standards is the responsibility of each state through the development and implementation of State Implementation Plans (SIPs) which limit emissions from existing sources, set time tables for compliance and establish monitoring procedures. The Agency is also responsible for setting New Source Performance Standards (NSPS) to limit criteria air pollutant emissions from new sources or from existing sources which have been modified based on the use of best demonstrated control systems. In areas where the air quality is better than that required to meet primary and secondary standards, emissions from new or modified sources are restricted under the Prevention of Significant Deterioration (PSD) program.

In addition, EPA is responsible for limiting emissions of air pollutants that are hazardous to human health, but are not already regulated as criteria pollutants. National Emission Standards for Hazardous Air Pollutants (NESHAPs) have been set for asbestos, beryllium, mercury, benzene and vinyl chloride, and are under evaluation for radionuclides, arsenic, and coke oven emissions.

ORD provides the scientific data bases, methodologies, models, assessments, emission reduction technologies and corresponding quality assurance support to implement these legislative authorities. Eleven major issues have been identified within the scope of the air research program which cut across scientific disciplines and the pollutant-specific structure of the research program.

Major Research Issues

Dose-Response

What dose response information is needed to reduce the uncertainties associated with the adverse health effects of air pollutants under NAAQS and NESHAPs?

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Uncertainty about what levels of pollutant exposure produce adverse health effects makes it difficult to set standards that will protect the public from those adverse health effects. A primary source of this uncertainty is lack of sufficient dose-response information to determine the lowest level of exposure to a particular pollutant at which adverse effects occur. Without this evidence the optimum level for a standard that adequately protects the public health cannot be determined. Research is being conducted to provide needed dose-response data on both criteria pollutants and hazardous air pollutants.

For each of the criteria air pollutants, the sensitive population groups and the pollutant exposure ranges of interest have generally been identified. However, testing of these pollutants will continue in both animal and human subjects to refine the exposure levels and the health endpoints of concern. These health endpoints are mainly respiratory, metabolic, and immune system effects for O_3, NO_2, SO_2 and particulate matter; cardiovascular and neurologic for CO; and behavioral effects for lead. Additional emphasis will be placed on evaluating the effects of long-term versus short-term higher-peak exposures to oxidants, particularly NO_2, and the effects of both long-term and short-term exposures to the coarse fraction of airborne particles smaller than 10 microns in diameter. The information obtained from this research will be factored into the next round of criteria documents and used in the review of NAAQS.

For hazardous air pollutants, a somewhat different approach is being taken. Research to identify which pollutants are of greatest concern, either because of the seriousness of their effects or because of the degree of exposure to them, will be conducted. Compounds will be studied in animals or in animal biological test systems to characterize and quantify their effects, particularly mutagenic or carcinogenic effects and effects upon particular organ systems. Because of the potential hazards of these pollutants, clinical studies of exposed human volunteers cannot be conducted; however, epidemiological studies may be feasible.

Studies on the health effects of motor vehicle exhausts will be conducted by the Health Effects Institute (HEI). This institute was established and is funded by both EPA and the motor vehicle industry to perform independent studies and produce health data on pollutants emitted from motor vehicles. The HEI considers a summary of the needs submitted by the sponsors and designs a health research program to respond to those needs. This program is complementary to EPA's research program for both criteria and non-criteria pollutants. HEI's research currently focuses on carbon monoxide, nitrogen oxides, and diesel exhaust.

Extrapolation

What models are needed to extrapolate from animal data to human risks, from high to low doses and from acute to chronic effects?

The lack of data on health effects in people exposed to air pollutants is a source of uncertainty in the development of NAAQS and NESHAPs. Even where human health data exist, they are often based upon short-term, high-level exposures which may not be directly relevant to the low-level, long-term chronic exposures that are more typical of environmental conditions. This data gap often cannot be filled by human clinical studies because one cannot intentionally expose human subjects to substances suspected of causing permanent damage.

Thus, to improve our ability to relate animal data to actual human consequences, and thereby develop more reliable risk estimates of exposure to air pollutants, techniques are being developed to extrapolate from animal to human effects, from high to low doses and from acute to chronic effects. To develop these techniques, information in three critical areas is needed: dosimetry—the amount of pollutant which reaches specific target sites in the body after exposure to a given concentration of pollutant; species sensitivity—the potential variations in response of different animal species to the same dose of pollutant; and dose-response.

For the criteria air pollutants, human volunteers can be exposed to pollutants for brief periods of time at concentrations similar to those encountered in daily life, and the resulting effects on heart and lung function, immune response, and other physiological and biological parameters can be measured through non-invasive techniques. Similar studies with animals can be conducted. Animals can also be exposed chronically to these pollutants and the cumulative lifetime effect of these exposures determined. This dose-response data combined with dosimetry and species-sensitivity information will enable an inference of the effects that chronic exposure to a given pollutant may have on humans. Both the experimental and theoretical work necessary to accomplish this for the criteria pollutants will be conducted.

The kind of extrapolation approach described above cannot be used with hazardous air pollutants since the health effects are likely to be chronic, severe, or irreversible, e.g., neurotoxic, genetic, reproductive, or developmental effects. Thus, research will concentrate on developing animal models that use biological indicators of such effects in humans.

Integrated Cancer Project

What research is needed to determine the contribution of air pollution to the incidence of cancer in the United States?

There is a great deal of uncertainty regarding the relationship between air pollution and human cancer. Determining the extent to which air pollution is responsible for or related to lung cancers and other types of human cancers could have a major impact on EPA's regulatory program. Thus, a long-term, interdisciplinary research program has been developed to

address the major scientific questions regarding the relationship between air pollution and human cancer.

The three basic goals of this program are to: (1) identify the principal airborne carcinogens; (2) determine which emission sources are major contributors of carcinogens to ambient air; and (3) improve the estimate of comparative human cancer risk from specific air pollutant emission sources. Field tests of relatively isolated single-source categories are essential for developing methods to evaluate the more typical multiple-source-category environments that the general population is exposed to. Therefore, the initial field tests will focus on quantifying carcinogens emitted from residential wood-fired combustion systems and motor vehicles. This project focuses on identifying those substances actually present in the air that are most likely to be carcinogenic and on describing how they came to be present in the environment. Thus, under the monitoring component of the project, samples of ambient air in the "breathing zone" of persons in an urban/industrial area and a suburban area will be collected and analyzed for carcinogens and mutagens. Comparisons between the ambient and personal samples and between the urban and suburban concentrations will be made, and relationships between exposure and dose will be studied. The relative importance and contribution of gaseous and volatile organic compounds, semi-volatile and particulate organic compounds to total airborne carcinogens will be determined. In addition, laboratory studies will be conducted to determine the atmospheric formation and fate of bioactive compounds.

Under the health component of the program, methods will be developed and data gathered to evaluate the human cancer risk from individual and, ultimately, complex-source emissions. A comparative methodology will be adapted to evaluate and utilize short-term mutagenesis and animal carcinogenesis data on emissions. Research to identify the major sources of hazardous air pollutants and to characterize these emissions from industries and combustion sources of primary concern will serve as the basis of the engineering component of the project.

Welfare Effects

What information is needed on the welfare effects of pollutants to support secondary standards?

Research of the impact of air pollution on vegetation and visibility degradation is needed to assess the need for secondary air quality standards for criteria pollutants. Research on the impact of O_3 on agricultural crops indicates that physiological conditions such as water stress on plants and O_3 exposure fluctuations may affect plant response to O_3. Therefore research to reduce these uncertainties will be conducted.

To develop and implement air pollution abatement strategies for visibility protection, research will be conducted to determine

the extent of visibility impairment, and analytical tools will be developed to assess a variety of control options. Specifically, the role of aerosols on visibility reduction will be assessed; visibility trends for the U.S. will be determined utilizing existing data bases; and measurement and monitoring techniques will be developed to more completely characterize the extent of visibility changes. A regional visibility research network, using fine particle and optical measurements, will be established to provide data for analyzing source-receptor relationships, and models to assess visibility protection strategies will be developed and refined.

Ambient Air Quality Models

What information on the atmospheric transport and transformation of air pollutants is needed to develop and improve ambient air quality models in support of regulatory programs?

Pollutants emitted into the air often undergo chemical and photochemical reactions that change the initial pollutants into different compounds. Models to predict this phenomenon are being developed at the urban and regional scale and for complex terrains. These models, when fully developed, will provide information necessary to develop, evaluate and implement cost-effective air pollution control strategies for SIPs and Prevention of Significant Deterioration determinations.

Over the last few years, a variety of air quality models have been developed and evaluations of these models indicate that they need to be improved to increase the accuracy and reliability of modeling predictions. To improve urban scale models (up to 50km), smog-chamber studies will be conducted to simulate the atmospheric chemical processes associated with the formation of oxidants and inhalable particulate matter including fine and coarse particulate size ranges. Emphasis will be placed on the impact of lower hydrocarbon/NO_x ratios and the role of specific categories of volatile organic carbons (VOCs) such as aromatic hydrocarbons and aldehydes in producing oxidants. Other studies will be conducted to determine the occurrence, lifetimes and transformation processes associated with potential hazardous air pollutants to assess their environmental importance.

On the regional scale (up to 1000km), laboratory and field studies will be conducted to improve the ability of models to predict the atmospheric transport, transformation and deposition processes for air pollutants such as O_3 and particulate matter. Alternative mathematical techniques and new meteorological tracers will also be evaluated to determine their ability to improve modeling predictions.

In addition, complex-terrain models will be field-tested to expand the applicability of the model to more complex topographical situations, a greater variety of meteorological conditions, and 3- and 24-hour average concentrations.

Mobile Source Emissions

What mobile source emission characterizations are needed to evaluate the effectiveness of control strategies?

As the driving fleet ages and changes occur in engine design, models to assess the impacts of mobile source emissions on ambient air quality need to be refined and studies need to be conducted to evaluate the health and environmental impact of new emissions. Greater emphasis will be placed on evaluating promising alternative fuels, particularly methanol. The two primary pollutants of importance from methanol-fueled vehicles are methanol and formaldehyde. Analytical procedures to measure methanol and formaldehyde will be developed and emission characterizations performed. Research to determine the photochemistry of emissions from methanol-fueled vehicles will be conducted also. Emissions from future gasoline-fueled vehicles and diesel-fueled vehicles equipped with advanced control technologies will be characterized.

An improved method will be developed to determine the contribution of motor vehicle emissions to the ambient air. This method will replace less applicable methods currently used. Past and present research efforts have focused on the development and refinement of a general exposure methodology for predicting population exposures to mobile sources emissions, using CO as a surrogate for mobile source emissions. Methods are not currently available to determine exposure conditions for most of the pollutants emitted from mobile sources. Because the dominant source of CO is mobile emissions, CO has been used as a surrogate for these other pollutants. The general exposure methodology used for CO will be extended to other mobile source pollutants. Vehicular exposure models will be developed for CO and other mobile source pollutants based on previous CO field studies. NO_2, inhalable particulates and benzene are potential candidates for study. Monitoring of these pollutants in highway microenvironments could additionally be used to evaluate the accuracy of these models. This information will be used to determine whether changes/additions to the current mobile source emission standards will be necessary.

Monitoring Systems, Methods Development and Quality Assurance

What monitoring systems and methods and quality assurance support are needed to support NESHAPs, NAAQS and SIPs?

New and improved air pollution monitoring methods and techniques are needed to develop risk assessments and determine areas where public health and welfare are threatened, air quality trends, compliance with ambient standards and permit conditions, and the need for enforcement actions. Such methods are needed for ambient, source and personal monitoring.

Methods Development. Few serious monitoring or methodology problems exist for current criteria air pollutants. Therefore, with the exception of inhalable particulate methods research, the primary focus of the research program in this area will be to refine existing ambient and source monitoring methods. Efforts to improve the sensitivity, reliability and precision of the methods and reduce their complexity and expense will be continued. Emphasis will also be placed on improving continuous source methods for monitoring SO_2, NO_2 and O_3.

Unlike the situation for criteria air pollutants, few monitoring methods are available for measuring the concentration of potentially hazardous air pollutants, especially VOCs. New sampling and analytical systems and a set of validated source-sampling methods will be developed for monitoring important sources of hazardous air pollutants that cannot now be monitored with adequate precision and accuracy. Research to develop methods of monitoring ambient hazardous air pollutant concentrations will be accelerated, as will work on passive monitors and new sorbents. This will extend the measurement capability to chemicals not collected by current methods and to new monitoring situations such as exposures near hazardous-waste sites. Following the development of appropriate monitoring technology, a nationwide Toxic Air Monitoring System (TAMS) will be established to characterize urban atmospheres and determine national trends for non-criteria air pollutants in order to determine the magnitude and extent of the hazardous air pollution problem.

Although conventional criteria pollutant monitoring programs have emphasized the measurement of pollutants in the ambient air, very little is known about actual human exposures to air pollutants. Studies now indicate that measurements at fixed sampling locations may not be representative of the concentrations to which key portions of the population are exposed. Thus, research to develop and refine methods for measuring actual human exposure will continue. Emphasis will be on technological improvements in personal (microenvironment) monitoring equipment and the development of adequate exposure models.

Quality Assurance. To ensure that Agency decisions are backed by technical data that are of known accuracy and precision, EPA will continue to provide quality assurance (QA) support in accordance with Agency policy and in support of QA requirements contained in regulations. The repository for reference samples will be maintained, standard reference materials developed and audits performed. State and local criteria pollutant air monitoring activities will continue, and QA support will also be provided to EPA, state and local governments, and international monitoring programs for criteria and non-criteria air pollutants.

Human Exposure

What monitoring systems and methods are needed to define human exposure to air pollutants?

Information on the concentrations to which people are actually exposed is becoming an increasingly important factor in determining the health risk associated with airborne contaminants. Through advances in miniaturization, it has been possible to design small instruments, called personal monitors, capable of accurately recording the concentrations of a pollutant to which a person is exposed. Successful personal monitors now exist for carbon monoxide (CO), volatile organic compounds, and respirable particulates. A limited number of field investigations have been undertaken with these new instruments.

A continuous CO personal monitor now exists using a small pump. However, this pump is battery operated and requires a technician to collect stored data and recalibrate the monitor every 12 hours. Therefore, there is a need to develop a small, lightweight passive CO monitor which will operate like the film badges used in radiation monitoring. There also is a need to improve the accuracy and precision of organics monitors. Laboratory research is under way to develop a passive monitor for volatile organic compounds and pesticides. Because the health effects of NO_2 are thought to be associated with high exposures of extremely short duration, a continuous NO_2 monitor is called for. Over the next several years, research will be conducted to develop such a monitor based on chemiluminescent principles and evaluated in pilot-scale field studies. If the instrument proves successful, it can be utilized in large-scale epidemiological studies on the sources, exposures, and health effects of NO_2. Field tests for existing monitors for inhaled particles will also be conducted and size-selective particle samplers may be developed.

As the new air pollution exposure instrumentation is developed, there will be a need to move from the laboratory into small-scale pilot field investigations to test these monitors in real settings. Once the personal monitoring methodology has proved effective on a small scale, it will be appropriate to demonstrate the methodology with full-scale studies on urban populations to better assess the public health risk from these pollutants.

Emission Characterization and Technology Evaluation

What stationary-source-emission characterizations and technology evaluations are needed to support SIPs, NSPS and NESHAPS?

Although considerable progress has been made in controlling air pollution from both mobile and stationary sources, emissions of the criteria pollutants are currently a major concern in a number of areas of the country. Thus, research will be conducted

to characterize the emission sources, and evaluate and improve the cost effectiveness of emission reduction technologies, thereby reducing the cost of complying with SIPs and New Source Performance Standards (NSPS).

Because much is already known about criteria pollutants, priorities for this research have shifted in recent years to focus more on VOCs and hazardous air pollutants. In addition, large-scale demonstrations of emission-reduction technologies have been replaced by less-costly fundamental studies, pilot and prototype testing and evaluation and technology-transfer activities.

VOCs, which react with NO_x and sunlight to produce ozone, are a major cause of the ozone non-attainment problem. Although emissions from major stationary sources are being reduced, small sources (e.g., dry cleaners, gas stations and paint users) are not being widely controlled. Although these sources individually emit small amounts of pollutants, collectively they may constitute a significant problem. Control technologies such as industrial flares, carbon adsorption, catalytic oxidation and thermal incineration will be assessed to determine their performance and cost in reducing VOC emissions from such sources. Emphasis will be placed on developing and evaluating methods to control VOCs without resorting to costly add-on control devices.

Research on VOC control technologies is not only important in resolving the ozone non-attainment problem, but in controlling hazardous air pollutant emissions as well. Thus, additional research will be conducted to assess the performance and determine the degree of hazardous air pollution control presently being achieved by technologies designed to control or reduce the formation of criteria pollutants. Alternatives will be evaluated and emission sources characterized.

Research to control particles focuses on improving the performance, reliability and cost-effectiveness of the multi-stage electrostatic precipitator (ESP) and fabric filtration. The major purpose of this research is to improve collection of small particles which have become increasingly important in meeting particle standards. ESPs may assist in acid rain mitigation for use with dry add-on SO_2 removal processes and switching to low-sulfur coals with their more difficult-to-collect fly ashes. The performance of fabric filtration can improve with the application of electrostatically augmented fabric filtration (ESFF). The effects of precharging and particle charge on filtration performance will be assessed. Recent research indicates that a pressure-drop-reduction by a factor of three or more can be achieved by properly conditioning the particulate matter, thus resulting in fabric filters one-third the size of conventional units. Additional research to verify this finding is being conducted.

Research to control NO_x will focus on evaluating the applicability of combustion modification techniques to industries and

utility boilers, refinery process heaters, cement kilns and stationary engines. Also, advanced methods such as reburning (fuel staging) and changes in precombustion burner designs will be assessed.

Summary of Long-Term Trends

The goals of the Air research program over the next five years are to: (1) improve risk-assessment capabilities to support existing and planned ambient air quality standards, hazardous air pollutant standards and source emission limitations; (2) provide the scientific data and technical support to implement control strategies and ensure compliance; and (3) identify future environmental problems.

To improve our risk assessment capabilities, ORD will continue to strengthen both the health and environmental effects research programs. In the health area, the effects of acute and chronic exposures to criteria air pollutants on humans will be more accurately defined and data on exposure levels refined. Techniques to more accurately identify the presence of hazardous air pollutants will be developed. Subsequent dose-response studies will be conducted to assist in the characterization and identification of health effects. The scientific data base necessary to develop a quantitative evaluation suitable for estimating the human cancer risk from both complex mixtures and individual chemicals will be developed. As the data base on the dose-response of air pollutants is expanded, increasing emphasis will be placed on improving the ability to relate these data to actual human consequences. Methods to extrapolate the data from animals to humans, from high to low doses and from acute to chronic effects will be developed and improved.

Increased emphasis will also be placed on monitoring human exposure to air pollutants. By increasing our knowledge of exposure concentrations, our ability to make health risk assessments will also improve.

Research to support the possible development of secondary standards will continue to focus on evaluating the effects of air pollutants on vegetation and visibility. Research to assess the impact of air pollution on vegetation will shift from O_3 to SO_2 and NO_2. Research to examine source-receptor relationships and lay the framework for a more comprehensive visibility monitoring program will be accelerated.

To support the development of control strategies and ensure compliance with these strategies, ORD will continue to maintain strong modeling, monitoring and engineering programs. For criteria pollutants, ambient air quality models will be refined to improve their predictive capabilities. Greater emphasis will be placed on studying the transport and transformation of O_3 and particles on the regional scale and developing more sophisticated complex-terrain models. Monitoring systems for criteria pollu-

tants will be refined to increase their accuracy and precision, and engineering evaluations will be conducted to improve the cost-effectiveness of control technologies for criteria pollutants. Increased emphasis will be placed on VOCs as precursors of O_3.

Also, research to determine the nature and the extent of hazardous air pollution problems will be accelerated. Analytical tools such as pollutant dispersion models will be adapted from air pollution models to improve health and exposure assessments. A national Toxics Air Monitoring System will be put into place and data collected on what pollutants are present in urban atmospheres and their concentrations. Trends data will be analyzed and new monitoring methods will be developed for use in the monitoring systems. Engineering research to bring sources of VOCs into compliance should not only reduce O_3 levels but air toxics emissions as well.

Hazardous Wastes

Hazardous wastes and their impacts on human health and the environment remain a major public problem. The Agency has recognized for several years that conventional land disposal of many high-hazard wastes is an incomplete solution to the problems they represent. Due to the possibility of leakage from land disposal facilities, wastes containing toxic, highly persistent and highly mobile chemicals must be carefully managed if they are to be placed in land disposal facilities. Moreover, Federal law now directs, through the recently enacted amendments to the Resource Conservation and Recovery Act (RCRA), that waste containing certain chemicals could be banned from forms of land disposal unless EPA determines that the prohibition is not required to protect human health and the environment. Therefore, methods are needed to evaluate the human and environmental risk associated with these chemicals. In addition, if wastes are to be banned from landfills, there is a need for adequate alternative technologies to ensure their safe disposal. EPA's research program will increase the emphasis placed on tests for determining waste toxicity, on predicting waste movement in the subsurface, and on new means of detecting wastes in the subsurface environment. More emphasis is also being placed on evaluating technological alternatives to land disposal.

In addition to the above, the recent passage of the RCRA amendments will result in increased emphasis on certain existing research programs and the start of new research efforts. The major research areas affected are: (1) control of leaking underground storage tanks, (2) disposal of high volume mining and utility wastes, (3) underground storage of hazardous wastes, (4) double-liner requirements for land disposal facilities, (5) special requirements for generators of small quantities of hazardous waste, and (6) environmentally acceptable disposal of industrial and municipal "non-hazardous" solid wastes to conventional land disposal facilities (Subtitle D).

To address these problems, nine major research issues have been identified for the hazardous waste program. These issues are: procedures for identifying and measuring chemical wastes; assessment and control of dioxins and other high-hazard wastes; assessment of the potential exposure to and effects of hazardous wastes; evaluation of technologies to manage uncontrolled waste sites; development and evaluation of technologies as alternatives to land disposal; information on equipment and procedures required to protect the health of personnel involved in hazardous waste handling; procedures to prevent and contain hazardous releases; quality assurance; and data to support development, permitting and enforcement of

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treatment, storage and disposal regulations. Many of the results from this research may also be of use in the Superfund effort.

Major Research Issues

Identification and Measurement of Chemical Wastes

What new analytical methods are needed to identify hazardous wastes and their chemical constituents?

More than 100 analytical methods have been proposed by EPA for analyzing waste samples and environmental samples that might be contaminated with any of the hundreds of chemicals classified as hazardous wastes. These are primarily chemical methods but also include methods for analyzing physical and biological properties and for determining the mobility of wastes. Most of these methods were developed for use in other media. Many of the proposed analytical methods are of necessity already being used by federal, state and industrial laboratories even though less than ten percent have been adequately validated. The cost of fully validating a single method is high, and can take from one to three years. Such validation, however, is important because completion of a systematic validation procedure can significantly enhance the Agency's or industry's confidence in the method. Therefore, priority will continue to be given to methods validation. Methods will be modified and alternative methods will be substituted when appropriate. Considerable effort will be devoted to reducing the costs and time associated with validation procedures without sacrificing the integrity of the process.

New hardware and software developments offer considerable promise for reducing the costs and time, while improving the sensitivity, of laboratory analyses. Examples of these emerging technologies are superconductive fluids, tandem-mass-spectrometry, and thermospray injection. Considerable effort will be directed to evaluating and applying such technologies for hazardous waste analyses. One particular thrust will be in the development of technologies for rapid screening of large numbers of samples, particularly groundwater samples. A second effort will be toward obtaining more comprehensive chemical profiles of volatile and semi-volatile organic chemicals in solids and other complex matrices. Concurrent with these activities will be a continuing effort to upgrade the computer programs supporting the analytical equipment, with special attention to computer interpretations of measurements.

Improving the Agency's capability to assess subsurface contamination problems will continue to be a high research priority. Evaluation and documentation of the capabilities of remote monitoring techniques—electromagnetic, resistivity, radar, seismometers—in different types of subsurface environments will continue. The feasibility of using laser/fiber-optic tech-

nology for long-term monitoring of groundwater will be demonstrated at the Environmental Monitoring Systems Laboratory/Las Vegas test site. Improved monitoring-well construction techniques will be developed and tested together with more efficient sampling procedures. Of particular concern is the statistical basis for the location and frequency of sampling activities, both in soil and in groundwater.

High-Hazard Wastes

What new information is needed to evaluate and control high-hazard wastes and to continue implementing the National Dioxin Strategy?

There is a need to develop a better scientific and engineering basis for assessing the technical feasibility and cost of technologies for the safe disposal, storage, destruction or detoxification of highly hazardous wastes, including such chemicals as dioxins, dibenzofurans and other halogenated organic wastes. A long-term research plan will be developed to address existing gaps in knowledge. Research will support the development of new regulations and guidance required under the reauthorization of the Resource Conservation and Recovery Act (RCRA). The research will provide evaluation procedures to be used by permitting agencies for the management of high-hazard wastes.

It is not yet known whether chemical or biological methods are safe or effective for *in situ* cleanup. The possible use of genetically engineered microorganisms holds particular promise, but serious questions exist concerning the appropriate control of these organisms and the safety of their metabolic residues or by-products. Biological and chemical controls are not as well understood as traditional land disposal or incineration technologies, and must be rigorously tested and evaluated. Laboratory studies will be followed by small-scale engineering or field demonstrations, with careful monitoring of by-products. Special emphasis will be directed to the potential hazards of genetically altered organisms and their appropriate controls. A separate effort is being conducted elsewhere in the program to determine the conditions under which hazardous wastes can be safely land treated or farmed.

Waste Characterization

What information is needed to characterize the potential exposure and effects posed by hazardous wastes?

Assessments of the exposure and effects posed by the disposal of hazardous wastes require knowledge regarding the sources and characteristics of hazardous wastes, the chain of events by which populations are exposed to the wastes, and the relationships between doses and their environmental or physiological responses. Major scientific uncertainties exist in the following areas: the quantity and types of hazardous wastes that escape

into the environment under various disposal methods; the concentrations of contaminants that result from different pathways through the environment; the actual dose received; and the effects caused by that dose. The uncertainties are amplified because most hazardous wastes consist of mixtures of many chemicals exhibiting different physical, chemical and toxicological properties, while current knowledge is mainly based on single chemicals. Adapting technical capability to the complex mixtures of chemicals typical of hazardous wastes will require significant effort over the next few years.

The EPA has significant research programs addressing these uncertainties, many of which are supported under other programs. These include in particular the groundwater program and the drinking water health effects program described in the Water chapter. The groundwater research program, supported under both the drinking water and hazardous waste research programs, is addressing the movement and transformation of chemicals in the subsurface by many processes, including advection, sorption, oxidation and biotransformation. These studies, conducted under both laboratory and field conditions, will reduce exposure uncertainties. The drinking water health program has two major areas important to hazardous waste problems. One activity addresses the toxicological effects of compounds which occur in groundwater, especially volatile organic chemicals. The second is development of methods to determine the effects of complex mixtures in drinking water.

A program to develop more accurate methods for predicting the quantity, composition and volatility of leachates from land disposal of wastes is just beginning. These and other methods for determining the escape of hazardous wastes into the environment, as well as predictive models in air, surface water and groundwater, will have to be combined into multimedia tools for exposure assessment.

A major effort will be directed toward determining which wastes should be considered hazardous. Methods will be developed that will identify as hazardous those wastes containing constituents at levels exceeding those at which human health and the environment is adversely affected. Short-term screening tests of biological effects (bioassays) are being developed to quickly and cheaply determine the toxicity of mixtures. These tests are being adapted from available bioassays into a system so that a number of toxicities and target organ effects can be evaluated simultaneously. Included are tests for agents that cause general toxicity, genetic damage, cancer, immune disorders, nerve damage, and reproductive and birth defects.

Structure-activity relationships, also developed for single chemicals, are being adapted and applied to hazardous wastes as well. Such studies will investigate the use of chemical and structural similarities to estimate health and environmental fate and effects.

Uncontrolled Dump Sites

What new control technologies and information are needed for the effective management of uncontrolled waste sites?

The National Priority List currently contains 546 hazardous waste sites, and as many as 2,200 may ultimately be listed. Emphasis to date has been on the removal of hazardous materials stored on the surface, and local containment of the pollutants found in soils and groundwater. Local containment methods have only been used on hazardous wastes for a short period, and their long-term effectiveness and reliability are unknown. Further development is needed to "customize" them to hazardous waste conditions and to determine the effective life-span of containment methods, their maintenance requirements, and their alternatives.

Contaminated soils, saturated zones, and groundwater are common at uncontrolled sites, and the technology to clean up these situations is in its infancy. Currently, the only proven method for soils decontamination is removal and burial in secure landfills. Groundwater requires collection, often by pumping, and treatment. Methods are needed to decontaminate soils and groundwater on-site.

Studies on containment systems will concentrate on refining the methods for hazardous waste situations and ascertaining the effectiveness of the systems under realistic situations. The results from these efforts will be utilized to prepare design manuals. Since containment is only a temporary measure, the emphasis of the program will be on the demonstration of on-site destruction technology including treatment systems and *in situ* immobilization and detoxification.

In situ processes will receive the major emphasis. Most of these technologies are now in laboratory or pilot stages, and the most promising methods should be at the demonstration stage by the end of this decade. If proven successful, these methods hold promise of being a major solution to the uncontrolled dump site problem. Existing soil and water treatment systems and equipment will be field-demonstrated to determine their operating characteristics and effectiveness, and new or innovative systems will be sought, evaluated, and field-tested.

A major effort is being initiated to study RCRA subtitle D waste facilities including municipal sanitary landfills, on-site industrial landfills, surface impoundments, and land treatment units. Based on 1979 data there are over 275,000 operating solid waste facilities of these types in the United States. It is suspected that many of these are generating hazardous leachates and surface runoff and should be investigated. The studies will determine whether the present monitoring criteria are adequate to protect human health and the environment.

Alternative Technology

What additional information is needed to develop, evaluate, or support alternatives to land disposal of wastes?

The current trend is toward eliminating land disposal of certain classes of untreated hazardous wastes. The banning of these wastes from land disposal could require proven alternative technologies for treating or recycling the waste materials. Although many of these technologies now exist, there are numerous questions regarding their effectiveness on specific wastes and their capacity to treat the anticipated volumes of hazardous wastes.

The Agency's research program on alternative technologies consists of a broad program to assess the environmental impacts of the major alternatives now under development, and in selected instances to support the evaluation of processes found by the Agency to offer substantial improvements over conventional hazardous waste disposal methods. These evaluations, together with existing data, will form the basis for treatment standards to be promulgated by the Agency.

The major research activities will consist of the performance evaluation of individual treatment processes and combinations of processes at pilot or field-scale tests. This program is to be based initially on a matrix of waste types and technologies. Initial emphasis will be on the priority technologies and waste streams identified by the Office of Solid Waste, followed by other techniques for processing potentially banned wastes. The nine technology areas are biological treatment, activated carbon, incineration, neutralization, oxidation, precipitation, reuse/recycle, solidification and dechlorination.

Personnel Health and Safety

What data are needed to ensure the health of waste-site personnel?

EPA personnel are directly involved as supervisors or project managers at hazardous waste sites, chemical-release investigations and cleanup operations where the use of protective clothing and other safety equipment is mandatory. These operations are anticipated to expand significantly as more Superfund remedial actions are undertaken. In addition, EPA has the responsibility to regulate and certify appropriate protective equipment for agricultural workers exposed to hazardous chemicals.

Promising new protective clothing and other safety technology for hazardous chemical activities will be subjected to laboratory and field evaluations to determine their safety, efficiency, and economics. In addition, field and laboratory test methods will be studied and, if necessary, new methods will be developed to

evaluate protective clothing performance under a variety of chemical challenges and operating conditions.

A chemical-protective ensemble will be subjected to testing and evaluation to fully assess its safety while maintaining acceptable comfort and protection levels. Research will also develop permeability data on protective clothing material, protective clothing test methods for the field and laboratory, and manuals and guidelines describing these test results and new products in order to assist users in making safe and effective equipment choices for a variety of exposure situations. Research will continue with the development and testing of suitable respirators, personal cooling devices and communications equipment for personnel wearing full protection suits.

Control of Hazardous Releases

What new techniques are needed to adequately prevent, contain and clean up accidental discharges of hazardous materials?

Accidental releases of oil and hazardous material to the land and water occur frequently and constitute a significant environmental hazard. Federal, state and local emergency response personnel require improved technologies for the prevention and control of hazardous material releases to make cost-effective, environmentally sound cleanup decisions.

A major area of uncertainty is in the use of chemicals and dispersants for oil and hazardous release cleanup. Laboratory and field evaluations of chemicals used will be made to determine their cost effectiveness, application methods and environmental side effects. The Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT), located in Edison, New Jersey, will be utilized in these evaluations. In cooperation with other federal agencies, OHMSETT will continue to be used to test and evaluate the latest developments in oil spill containment and cleanup equipment and methods. This unique facility provides these agencies as well as states with the knowledge on what equipment to purchase and how to use it cost-effectively.

A continuing effort throughout this period will be the evaluation of new technologies for the prevention and cleanup of releases. Innovative new systems will be sought, and if shown to be feasible, field-evaluated.

Quality Assurance

What measures are needed to assure the reliability and consistency of techniques and data used in support of the hazardous waste program?

Quality assurance support provided to federal and state laboratories participating in activities associated with RCRA

will continue to expand, as will quality control and calibration standards for larger numbers of chemicals. Evaluations of laboratory performance based on the analyses of blind samples and on on-site laboratory visits will be increased in number and scope. Reference materials for a wide range of chemicals in complex solid and liquid matrices will be prepared using both naturally occurring and synthetic materials. Specialized training and technical support programs will be initiated to help state laboratories rapidly improve their capabilities to use RCRA analytical methods in support of state monitoring programs.

Representative and valid test samples and improved quality of sample analyses are also critical in site assessments. These activities include prior evaluation of contractor laboratories to conduct required analyses, provision of quality control and calibration standards, provision of standard reference chemicals, and support of an independent referee laboratory to assist with testing new analytical protocols and resolving particularly complex analytical problems. Support of field sampling activities will include improving the statistical basis for sampling programs, ensuring that problems of sample contamination are minimized and reducing delays in processing samples.

Emphasis will continue on improving analytical methods and documenting their capability to assess the chemical constituents of waste samples. Periodic reports describing available analytical methods, the state of the inter-laboratory validation of these methods, and the expected performance of the methods will be widely disseminated to EPA and state laboratories and contractors. In addition to methods that have been formally adopted by EPA for use in the hazardous waste or other regulatory programs, the reports will identify methods in various stages of development by the scientific community.

Regulatory Support

What technical information is needed to support the land disposal and treatment programs and the regulations governing incineration of hazardous wastes?

Historically, land disposal has been a commonly employed technique for disposal of hazardous wastes. In order to better provide environmentally safe control technology for hazardous waste land disposal, a system of improved control technology options will be developed within the next few years.

Land disposal will not be a "one-time" approval process. Technological advances could require a continuing application of research to support not only the initial permit decisions, but the development of improved monitoring techniques and the scientific basis for future regulatory modifications.

As the Agency moves to ban certain wastes from land disposal, various incineration methods are likely to become increasingly popular. EPA's Regional Offices and the states will require

technical information and assistance regarding the performance capabilities of hazardous waste incinerators to enable them to prepare permits under RCRA. Reliable, economical, realtime measurement methods are needed to allow enforcement officials to determine whether thermal destruction facilities are in compliance with the RCRA standards. Ensuring the safety of hazardous waste thermal destruction processes requires that methods be developed to predict performance, increase reliability through improved control of operational parameters and avoid conditions which produce hazardous combustion by-products. Extensive technical data are also needed to develop regulations and permitting approaches for the treatment of hazardous waste in high-temperature industrial processes. Data are needed on improved control methods to provide a technical basis for implementation of revised incinerator standards.

Research in thermal destruction will be on comprehensive laboratory and pilot-scale investigations to determine easily monitored parameters that can be correlated with waste-destruction performance. Emphasis will be placed upon developing methods that will assist enforcement officials as well as facility operators in determining the onset of process failure and avoiding emission of hazardous combustion products. This research will confirm these relationships and perfect monitoring techniques for measuring key parameters.

Guidance manuals to meet established RCRA standards for best operating practices of thermal destruction facilities will be produced. Of particular importance will be the development of reliable cost-effective techniques for real-time monitoring of facility performance. Standards on the use of these techniques will be provided to Regional Offices and state enforcement and permitting officials. Rapid compliance-assessment techniques will be developed and operating methods to control emissions of hazardous products of incomplete combustion will be determined.

The performance-validation approach will be applied towards the disposal options for landfills, surface impoundment waste piles and underground mines. Control technologies to be validated include cover systems, dike and slope stability, clay soil liners, synthetic liners, pollution collection systems and waste stabilization practices. In conjunction with these studies, the identification of pollutant leaching from surface impoundments will be required, especially for dioxin, contaminated soils and residues from new alternative technology systems.

New technical guidance documents will be developed to enable the regulated community and permitting officials to better prepare and review land disposal permit applications and to assure that the performance criteria are met. EPA's research program will also continue to provide direct technical support to federal and state regulators in cases where supplemental scientific support is needed. Remote sensing data, including both historical and current aerial imagery, will continue to

provide an indispensable tool in assessing RCRA sites and in the identification and assessment of uncontrolled dump sites. Interpreted photographs and multispectral scanner data assist in bringing action against illegal dumpers, determining priorities for remedial action and guiding entry into particularly hazardous areas. They also provide excellent documentation on the state of clean-up operations. General and site-specific guidance on the use of geophysical techniques for locating monitoring wells, for direct identification of buried wastes and containment plumes and for assessing subsurface features that relate to remedial actions will be expanded as this technology becomes more widely used. Geographical information systems will be used to combine aerial imagery and subsurface monitoring data together with soil, vegetation and other types of data that give a comprehensive perspective to the status of sites. Engineering support will be provided on characterizing wastes, geology, hydrology and soil conditions as they pertain to the feasibility of alternative approaches to conducting remedial action. Design plans, feasibility studies and performance specifications developed as the basis for remedial action will be reviewed.

Research addressing the issues identified in this chapter is likely to continue for several years. Monitoring and analytical techniques and procedures will continue to be improved, thereby lowering detection limits while reducing the costs of sample analysis. Improved monitoring and analytic procedures will facilitate implementation of both the RCRA and Superfund programs by allowing more state and private laboratories to participate in the programs, increasing the overall analytic capacity available and improving the overall ability to detect the presence of problem chemicals before they threaten human health or the environment.

Research supporting implementation of the National Dioxin Strategy will continue, but the magnitude of the effort will be largely dependent on the findings of the initial phases of the program. Specifically, the Agency will adjust its level of effort depending upon the extent to which dioxin contamination is found and the significance of its health and environmental effects. Additional research support will be undertaken to assess the risks associated with dioxin isomers other than 2,3,7,8-TCDD, as well as on some of the homologs, such as dibenzofurans.

As a result of Subtitle C of RCRA, EPA will promulgate standards for monitoring existing underground storage tanks. Monitoring systems will be developed to determine the location and extent of leaks from these tanks. In addition, remote sensing imagery will be utilized to conduct an inventory of the existing tanks.

Summary of Long-Term Trends

Research to characterize the potential exposure and effects posed by hazardous wastes will not only continue into the next

decade, but will likely be an area of significant growth. In order to come to grips with the hazardous waste problem and to be able to answer the questions and concerns of the general public, much will have to be learned regarding the behavior of hazardous wastes released into the environment and their effects on human health. Initial emphasis will be on assessing the potential for exposure via air, water and subsurface routes that result from various disposal practices. Although land disposal of many compounds could ultimately be banned, other options will pose different risks that must be identified and quantified. Also, health tests for predicting specific effects from waste streams will be essential to the regulatory program.

Development and evaluation of alternatives to land disposal of wastes will remain a high priority for the Agency and private industry. Exploration of alternatives is only in the beginning stages and much more research is needed in order for them to be available on a large scale to replace conventional disposal. Alternative treatments and disposal technologies will require extensive testing and performance information which will require research well into the next decade.

Research support for remedial actions and removal of hazardous materials accidently released into the environment will continue. The complexities involved in assessing hazards, choosing cleanup options, overseeing cleanup operations and ensuring the safety of public health demand that highly capable and knowledgeable technical support staff be provided through the duration of the Agency's emergency response activities.

Multimedia Energy

The overall goal of the multimedia energy research and development program is to provide the scientific and technical information necessary to support the Agency's permitting and standard-setting processes, and to allow for the development and utilization of energy sources in an environmentally acceptable manner. Research will be conducted to better understand the phenomenon of acid deposition and provide information upon which mitigation decisions may be made, expand EPA's knowledge of the performance, reliability, and cost of the limestone injection multistage burner (LIMB) control technology, and characterize and evaluate synthetic fuels discharges.

Research on acid deposition is coordinated through the National Acid Precipitation Assessment Program (NAPAP), which is administered by the Interagency Task Force on Acid Precipitation. EPA is one of three joint-chairs of the Interagency Task Force, and has the lead role in the aquatic effects, control technology and policy assessment research areas. The term "acid rain" means the atmospheric deposition of acidic or acid-forming compounds in either their dry or wet form. These compounds exist in the atmosphere as gases or aerosol particles containing sulfur oxides (SO_x), nitrogen oxides (NO_x), hydrogen chloride, sulfuric acid, nitric acid and certain sulfate and nitrate compounds. While scientists generally agree that these compounds are responsible for deposition of varying degrees of acidity, many questions still remain about the causes, effects, and methods of mitigating or controlling acid deposition. The objective of acid deposition research is to develop the necessary data to fully understand the sources and characteristics of acid deposition as well as the extent of damage or potential damage. This information is essential to develop effective corrective strategies.

A second major research area is the promotion of innovative cost-effective energy-related pollution control technologies. A promising area is the development of the "limestone injection multistage burner" (LIMB) emission-reduction technology. The LIMB combines SO_x control with simultaneous NO_x control by using a mixture of pulverized coal and limestone in a low-NO_x burner. This technology may lower the capital cost of SO_x control by a factor of 3 to 4 and annual operating costs by 50 percent.

To be accepted as a possible acid rain mitigation control technology alternative, LIMB has to be demonstrated by the

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end of this decade. The EPA-sponsored cooperative test programs with industry and the State of Ohio on a 105 mw wall-fired boiler will be completed in 1989.

The third research area is the development and evaluation of data on synthetic fuel processes, including the characterization of discharges, and the assessment of emission-reduction technologies for mitigating these impacts. These efforts assist industry and permitting officials in identifying problems which might impede the commercialization of the industry while ensuring the quality of the environment.

Major Research Issues

Emissions Inventories of Acid Precursors

How can emissions inventories be made more responsive to acid rain modeling and assessment needs?

Current emission rates for major categories of man-made acid deposition precursors are known with reasonable accuracy at the national level. However, atmospheric transport models under development will require improvements in spatial and temporal resolution of emissions estimates to be consistent with the detailed atmospheric chemistry treated by these models. The emission of ammonia and alkaline dust from natural sources and man-made environments must be quantified in order to properly use transport models. Without emissions data that match the model resolution, these models cannot be validated and used with confidence. Carefully validated emissions inventories for individual states would be required for future implementation of any additional emissions-control strategies. Depending upon the form future emissions controls may take, additional work would be required to better define the relevant emissions from each affected state in a specified baseline year.

Even greater uncertainties exist in any attempts to project future emissions, the effect of possible emissions-control requirements and their probable costs. The mix of emissions sources in any specific region may also change with time. The capability exists to predict such changes over the next decade or two.

Substantially more precise quantification of emissions rates will require the creation of new data bases on emissions factors (rate of emissions per unit of economic activity) developed through a concerted measurement program. For some source categories, it will be necessary to make these measurements independently for different regions of the country to account for climatic and technological variations. Compilation of emissions activities will be combined with the improved emissions factors to calculate emissions with the requisite resolution. Natural-emissions studies will focus primarily on the basic sciences governing the emission and transport of all chemical precursor

species, and on improving the quantitative emissions estimates of ammonia and alkaline dusts.

Efforts to project future emissions rates and to estimate the cost of alternative emissions-control strategies are dependent upon the development or improvement of models which replicate the behavior of each important "emitting sector" of the economy. Resolution of these questions will give policy-makers more insight into the relative urgency of the demand to control emissions. Improved models will also reduce confusion over the cost of any specified emissions-control strategy. These cost estimates need to be made consistently, with methods which have been fully reviewed by the engineering and economic communities. Emissions estimates will shift towards more reliance on actual data and detailed emissions models than on emissions-inventory development.

Atmospheric Processes Affecting Acid Deposition

How can the transport, chemical transformation, deposition processes and the exposure of ecologically sensitive areas and man-made materials be determined? The transport, chemical transformation, and deposition processes associated with acid deposition must be investigated on both the regional and local scales. These processes and the resultant source-receptor relationships are not so well defined that reliable estimates of the impacts of a given source or control strategy can be determined. Both an understanding of these processes and reliable numerical representation of the cause/effect relationships must be developed.

Source-Receptor Relationships. The development of control strategies to mitigate acidic deposition requires a means of determining source culpability. Significant uncertainties exist in the present understanding of the transport, chemical transformation, and deposition processes associated with the delivery of acidic substances to ecologically sensitive areas. Methods are required to assess the relative importance of local versus distant sources of emissions.

A Regional Acid Deposition Model (RADM) is currently being developed using both laboratory and field data. RADM is being developed as an assembly of model components (modules or submodels) to simulate transport, dispersion, chemical transformation, precipitation scavenging and dry deposition. These modules will be updated and revised as the uncertainties in the processes become better understood and characterized.

Local/Distant Deposition from Sources. The objective of this area of investigation is to determine the relative importance of local as opposed to remote impacts of major point and area sources. Currently, there are limited data on the influence of frontal storms, convective storms and urban areas on acidic wet deposition. Thus, it is necessary to assess the processes relating

to the transport, chemical transformation, precipitation scavenging, cloud chemistry and deposition of acidic substances and their precursors on the region.

Comprehensive sampling of air quality and precipitation chemical quality of frontal storms around a large urban area will be conducted. To develop information that can be used to provide assessments of materials damage, measurements of the distribution of gaseous sulfur dioxide and wet deposition of hydrogen ions as well as the location and magnitude of maximum concentrations of chemical species in ambient air and precipitation will be determined. These mesoscale modeling and assessment efforts will be coordinated with the development of the Regional Acid Deposition Model (RADM) such that the regional and mesoscale models are both consistent and compatible.

Measurements of Chemical Characteristics of Cloud and Mountain Forest Exposure. Throughout the primary regions affected by acid deposition, there are no routine measurements in the vertical dimension of gases and particles either in clear air, or of these constituents plus droplet chemistry in clouds. The uncertainties caused by the lack of data for mountain ecosystems hamper the investigations of the mechanisms of tree dieback and of reduced growth rates at higher elevations. These observed effects are very pronounced at higher elevations in the East, and appear to increase in severity with increasing elevation.

If possible, monitoring stations will be established on the slopes and summits of selected mountains and will be co-located with forestry research stations. Samples from the network of forestry research and monitoring stations will be analyzed and archived by a central laboratory. Development and standardization of monitoring instruments to perform reliably under the physically demanding conditions at these elevations will be required. A quality assurance and control program will be implemented to ensure the long-term usefulness of these data and their intercomparability among sites.

Measurements of air and cloud droplet chemistry will be provided as functions of time, geographic location, and elevation. Such observations will provide information on trends with time and will be used to address the effects observed upon mountain forest ecosystems. The observations will provide a means of estimating the exposure of mountain forest ecosystems to acid deposition by cloud droplets and other pollutants that may affect such ecosystems.

Dry-Acid Deposition Monitoring

What is the best method to obtain dry deposition monitoring data comparable to that from the existing National Trends Network (NTN) which concentrates on wet deposition?

The acid rain research programs are compiling a large volume of deposition data from wet precipitation. There is also some

evidence that dry sources of acid deposition in the form of dust and humidity constitute a potentially significant component of total deposition. However, very little data exist on dry deposition due to the difficulty in developing and deploying accurate monitoring instruments. Another problem is that the dry deposition rate varies with surface cover and topography, as well as with environmental variables such as wind speed and humidity. As a result, the actual contribution of dry deposition in most areas is only estimated within an order of magnitude.

The prototype monitors now being evaluated do not measure dry deposition fluxes directly. Instead, they measure ambient air concentrations and use empirical factors to estimate the dry deposition rate. These monitors will be deployed in a network, in many cases co-located with wet deposition collectors. The samples will be collected and analyzed in a central laboratory. The first few years will be dedicated to installing the network and making it fully operational. Once this is accomplished the research emphasis will be developing direct methods of measuring the dry deposition rate.

Aquatic Effects of Acid Deposition

What future changes in surface water chemistry will occur assuming current levels of acid deposition remain constant, and what is the extent and rate-of-change to aquatic resources stemming from acid deposition?

The effects of acidification are most pronounced in sensitive aquatic systems. Acidic deposition is believed to be a major contributing factor in episodic depressions of pH resulting, in some cases, in fish kills and other biological disturbances. Historical assessments have been uneven and of limited utility due to differences in sampling and analytical methodologies, potentially biased selection of samples, variable effects among different aquatic systems and a relatively small data base. The scientific uncertainties surrounding the aquatic effects of acidic deposition can be divided into several major categories: the extent of sensitive or acidic surface waters in the U.S.; the detection of long-term trends in surface water chemistry; modeling changes in surface water chemistry; and the biological effects associated with surface-water acidification. These uncertainties can be translated into questions of extent, rate, and magnitude of change attributable to acidic deposition.

National Surface Water Survey. In order to decrease the uncertainties related to the aquatic effects of acidic deposition, the EPA, in cooperation with the NAPAP Aquatic Effects Group, is undertaking a National Surface Water Survey (NSWS). The NSWS is a field project in three distinct phases to document the chemical and biological status of lakes and streams in regions potentially sensitive to acidic deposition. The Survey also will select regionally representative surface waters based on chemical, physical, and biological parameters to

quantify future changes in aquatic resources through a long-term monitoring program.

The first phase of the NSWS is designed to quantify the chemistry of lakes and streams in areas now believed to contain the majority of low-alkalinity waters. This phase of the survey will determine what percentage of lakes and streams in the susceptible regions are acidic or have low alkalinity. Phase II will quantify the biological components and the seasonal and spatial variability of a regionally representative subset of lakes and streams. These data should explain what percentage of lakes are devoid of fish, what chemical characteristics of surface waters are associated with the presence or absence of fish and what temporal variability can be expected in representative surface waters. The final phase will define those representative lakes and streams as regionally representative sites for a long-term monitoring program to quantify future changes in the chemistry and biology of aquatic ecosystems. The primary objective of this phase is to determine what chemical or biological changes are occurring in regionally representative surface waters and at what rate.

Long-Term Trends. The detection of long-term trends in surface water chemistry is critical to understanding the response rates of natural systems to acidic inputs from the atmosphere and how fast natural systems might acidify due to natural causes. EPA's long-term monitoring sites have been placed in areas in which there is little or no disturbance from human activities and which are remote from point sources of air pollution. However, their regional representativeness is not currently known. The National Surface Water Survey will establish the criteria for regional representativeness and in coordination with existing monitoring sites will improve regional tracking of the responses of surface waters to changes in acidic inputs.

Surface Water Chemistry Models. The production of reliable models of the temporal changes in surface water chemistry due to acidic inputs is one of the most important goals of the aquatic-effects research program. These models must be closely coordinated with the research in the terrestrial effects program, under whose auspices most of the watershed-level and soil processes work will be conducted. The most important effort in the modeling of surface water chemistry will be the estimation of the extent of direct response and delayed response systems in the U.S. This difference between response times is expected on the basis of soil, bedrock and hydrological differences among systems. Therefore, some watersheds will be in dynamic equilibrium with acidic inputs from the atmosphere and will respond quickly, while others will exhibit significant sulfur retention or contain appreciable buffering capacities and will respond only after long delays. If direct response systems prevail in sensitive areas of the country, then no additional changes in surface water chemistry would be expected, given no change in present acidic loading rates. However, if delayed response systems predominate, then more waters may become acidic due

to acidic deposition even if current loading rates do not change. This research effort will have a clear impact on the immediacy of the need for possible additional controls on sulfur emissions.

Biological Effects. The biological effects of acidified surface waters have historically been one of the issues driving the debate over acid rain. Initial research will establish the correlations between surface water chemistry and the status of fish populations. Fish populations may decline or disappear for many different reasons, however, so these correlations must be accompanied by the necessary research to establish cause-and-effect relationships. In order to do that, EPA will continue work that has already begun on the dose-response relationships between fish populations and concentrations of toxic metals (such as aluminum) that are thought to be elevated in acidic waters. EPA will also pursue work on the response of fish populations and other ecological endpoints in artificially acidified lakes as part of several large-scale on-going or planned studies. These studies will increase the certainty of the actual extent of declines of fish populations and other ecological effects associated with acidic deposition.

Terrestrial Effects of Acid Deposition

What is the extent, rate, magnitude and cause of observed effects to watersheds, soil properties and forests as a result of acid deposition?

Studies in the terrestrial effects of acidic deposition include effects on watersheds and soil properties and effects on forests. The major issues have to do with whether effects can currently be shown or suspected, their extent, their magnitude and the rate at which they occur.

Watersheds and Soil Processes. Many processes within watersheds affect the rate and final magnitude of the acidification of surface waters. Watershed bedrock and surficial geology, system hydrology and biological processes are all important determinants of the response of surface waters to acidic inputs from the atmosphere. Acidification of surface water is a watershed-level phenomenon, and full understanding of all the biogeochemical processes involved in watersheds is not expected for some years. However, EPA does expect to expand its knowledge of the processes to the point of more accurately predicting the effects of changing acidic inputs. EPA's research strategy for the next five years is two-fold. First, it will accelerate the process-level research in the geochemical and physical characteristics of soils that are important in the response of surface waters. Second, EPA, in collaboration with other agencies participating in NAPAP, will establish a network of carefully monitored watersheds in sensitive regions of the country. Data will be collected on all the relevant physical, chemical and biological parameters associated with surface water quality.

One result from this research effort will be improved predictive capabilities for the responses of watersheds to acidic inputs from the atmosphere and better ability to forecast the magnitude and rates of change in any relevant watershed due to changes in acidic inputs.

A second result will be the establishment of a network of carefully monitored watersheds for the purpose of detecting trends in watershed responses, especially changes in surface water quality that may be due to acidic inputs. However, natural systems are so variable that statistically reliable trends in surface water quality will take a much longer period than will improvements in predictive capabilities.

Forests. Preliminary data on foliar damage and growth reductions in several species of trees in different forest ecotypes reveal surprising similarities to more severe conditions that currently exist in Germany and central Europe. However, there is no clear indication of which of many possible mechanisms is most important. To establish cause-and-effect mechanisms will require a significant research effort and will likely continue into the 1990s.

EPA will be implementing a survey of forests in the U.S. designed to measure the extent of currently unexplained forest dieback and decline. While this survey cannot determine the causes, it should provide some estimates of the current and potential impacts of this problem.

EPA will also accelerate research designed to identify the cause-and-effect mechanisms of forest changes and the interactive effects of air pollutants associated with acidic deposition in order to fully understand the relative contribution that acidic inputs themselves have.

Near-term results will be limited to an improved understanding of the extent of unexplained changes in U.S. forests. In the longer term, EPA hopes to identify the roles acid deposition and associated air pollutants have in affecting forests, and what additional air quality controls might be needed, if any.

Materials Damage from Acid Deposition

What is the quantitative relationship between acid deposition and damage to structures, buildings, and other materials?

Qualitative relationships between acid deposition and resulting damage have been identified for a few materials under various conditions of exposure. The issue now is to quantify the rate of damage as a function of acid deposition, and to extend the development of damage functions to other materials. The assessment of the overall impact of acid deposition on materials also requires knowledge of the distribution of exposed building components.

The damage functions are being compiled from existing literature, retrospective analysis of exposed materials, physical chemistry theory, chamber studies and field exposure studies. As the basic mechanisms of these damage functions become better understood, the effort will shift to predictive models of materials damage that will allow accelerated studies in controlled-climate chambers. The studies will also be extended to more complex systems of materials, such as reinforced concrete, brick and mortar, and roofing systems.

A mathematical model of materials distribution will be developed from actual samples in several urban areas. To complete this inventory, materials associated with special uses such as transmission towers and high-rise buildings will be compiled from other data sources.

Acid Deposition Control Technologies

What current and emerging technologies exist for reducing emissions of SO_x, NO_x and other acid deposition precursors from fossil fuel combustion sources and industrial processes? What are the costs and benefits of these technologies when they are applied to new and existing emission sources?

The National Acid Precipitation Assessment Program, Control Technologies Task Group (H) has designed a program consisting of (1) monitoring of relevant Federal control technology developmental research activities of the EPA, the Department of Energy (DOE), and the Tennessee Valley Authority (TVA); and (2) implementing selected studies to assess the cost and performance of candidate control technologies for reducing emissions of acid deposition precursors. EPA's research efforts will be focused on developing and assessing methods and information on reducing emissions. This effort will include:

1. Developing engineering cost and performance information for current and near-term emerging SO_x and NO_x control technologies that could be applied to existing and new fossil fuel sources.

2. Assessing the current status of commercial coal cleaning (sulfur and ash removal) efforts as well as the potential and cost for further reductions in SO_x through expansion of this technology.

3. Developing a methodology for evaluating the feasibility of control technology options for the 50-100 major SO_x sources in the United States.

4. Developing engineering cost and performance information on current control technologies that could be applied to existing and new industrial processes such as non-ferrous smelting and iron and steel manufacturing.

5. Assessing the technical considerations and engineering costs associated with retrofitting the limestone injection multistage burner (LIMB) process to existing coal-fired boilers, including an evaluation of boiler type and particulate control requirements.

6. Developing engineering cost and performance information for technologies which will control volatile organic compound (VOC) emissions which may contribute to acid deposition.

Assessment

What existing mechanism(s) would best integrate acid deposition research information to provide policy-makers with the ability to formulate timely and cost-effective decisions for dealing with the acid deposition issues?

The goal of the assessment research program is to develop methods for comprehensive assessments of acid deposition evaluation and control strategies. These methods will deal quantitatively with the range of uncertainties around various data and their use. Developing methods to organize scientific results and applying them early in the program will ensure that the research results will be relevant to policy decisions.

Major acid deposition assessments are scheduled for 1985, 1987 and 1989. The 1985 report will encompass an assessment of current damage, an uncertainty analysis of key scientific areas, the implications of these uncertainties to policy alternatives, and a framework for the integrated assessment methodology to be used in the 1987 and 1989 assessments.

Methods for an Integrated Analysis of Acid Deposition. The integrated analysis of acid deposition research in 1987 and 1989 requires a framework that will incorporate the following elements into one comprehensive analysis: changes in emissions and costs associated with alternative emissions strategies; changes in deposition of substances in receptor regions of interest; changes in effects related to changes in deposition; costs and impacts of mitigation strategies; economic value of changes in effects; systematic uncertainty analysis; and methods for conveying the results of this analysis to policy-makers and interested parties. The 1987 report will incorporate all of these elements and linkages. It should be noted that the analysis may still be limited in coverage and quality. Data and scientific relationships may not be available to include all relevant pollutants, types of effects, and regions in all steps of the assessment. The 1987 assessment will, however, demonstrate a methodology which links the best available information in all of the areas in a consistent framework.

Estimating the Costs and Benefits of Reducing Acid Deposition. Research is being conducted to estimate the direct and indirect costs of emission control and mitigation strategies. Work is also

underway to add emissions and cost information for industrial processes, mobile sources and residential and commercial sources. Integration of these policies will be conducted using the Emission Strategy Integration Model (ESIM) which will accept cost-emission curves and solve for the minimum-cost fuel-technology mix that is consistent with region-specific emissions targets.

Benefits of Reduced Acid Deposition. The valuation of natural resource changes is a challenging task due to the complexity of theoretical and applied problems that will need to be addressed. Studies will be conducted to set values on the effects of acid deposition on forests, crops, recreational fishing, materials, natural ecosystems, regional economic impacts, and ancillary impacts such as effects on visibility.

Limestone Injection Multistage Burner (LIMB)

What demonstrations of LIMB technology are needed to document its effectiveness in reducing emissions of sulfur and nitrogen oxides?

Large coal-fired steam generators are major emissions sources of nitrogen oxides (NO_x) and sulfur oxides (SO_x). The EPA has successfully developed and demonstrated advanced low-NO_x burner technologies applicable to this class of sources. Many manufacturers are offering advanced burner technology for new and/or retrofit applications. An outgrowth of the low-NO_x burner development is an approach to achieve potentially lower reductions of SO_x and NO_x at a significantly reduced cost (3 to 5 times less than flue gas desulfurization) for retrofit applications. This LIMB (Limestone Injection Burner) approach involves SO_x-sorbent injection around the low-NO_x burners or at other points in the boiler. To bring the technology to commercialization will require a full-scale demonstration on a utility boiler of representative design. A demonstration of the technology is scheduled to be completed by 1990. This demonstration will be conducted on a 105 MW wall-fired boiler that will be modified to accommodate the LIMB technology. To support tnis demonstration, research will be conducted to determine what effects the process parameters have on sorbent activation and sulfur capture. Methods for obtaining highly reactive sorbents, for optimizing reaction conditions to achieve maximum capture and for minimizing sorbent costs continue to be developed.

Synthetic Fuels

What information or new technologies are needed to analyze or mitigate potential environmental impacts associated with the synfuels industry?

The entire synfuels energy area is in a state of change as a result of erratic fluctuations in world petroleum supply and demand. It appears that shifting national priorities will result in limited

near-term plant construction, but federal and private support has already placed a number of large facilities in operation. Depending on action by the U.S. Synthetic Fuels Corporation (SFC), more commercial plants may be constructed. EPA is assisting the SFC and project sponsors in the development of plans for the environmental monitoring of unregulated pollutants, as well as in the compliance monitoring of pollutants required by permits.

Data from SFC plants could be a primary source of information for future control technology assessments. However, the proprietary nature of developing technologies raise questions as to the availability of certain data to the EPA. This uncertainty requires that a continuing research effort be made to develop the requisite information by other means. Such activities as small-scale testing of controls, evaluations of controls on similar facilities (refineries) and engineering analyses of available control data shall have to be instituted.

There are potentially serious environmental impacts from synthetic fuels development including air and water pollution and solid wastes.

Air Pollution. Air pollution mitigation research will be principally focused on the development or transfer of appropriate sulfur control technologies. Because of the relatively high cost of sulfur control in synfuels operations, the level of emissions control may determine the total production capacity in certain regions, especially in the prime oil shale areas of Utah and Colorado. EPA's research will concentrate on innovative combustion approaches which may spur private sector initiatives. Other significant air quality issues requiring further research include particulate-organic-matter emission during startup and shutdown and the extent to which hazardous volatile-organic-carbons can be controlled through the addition of surface-active agents.

Water Pollution. The primary water pollution concern associated with synfuels is with the optimal treatment of wastewaters including the possibility of zero discharge. Standard wastewater treatment approaches such as activated sludge can be affected by a variety of extraction processes that include solvent stripping. When treated wastewater is used in cooling towers, there is the further potential of contributing additional air emissions. EPA is conducting research on organic constituents, but more study is required to reduce the chance of unacceptable emissions from cooling towers.

Solid Wastes. Further study is required to determine the potential for hazardous conditions arising from the leaching or evaporation of pollutants from synfuel wastes, especially where co-disposal of untreated wastewater with coal ash or oil shale residues is being considered. Oil shale processing produces tremendous volumes of solid waste, exacerbated by difficult stabilization and reclamation conditions. Development and

demonstration of technologies for effective cleanup and energy recovery from abandoned coal gasification waste sites is another solid waste priority.

Summary of Long-Term Trends

The research to understand the phenomenon of acid deposition and to provide a data and information base for policy-makers could take a number of different directions as the next decade is entered. The on-going interagency research program has a ten-year mandate from Congress which carries through 1990. However, both researchers and policy-makers realize that the phenomenon is one of the most complex and challenging scientific problems. They generally recognize that, although the accelerated research program will bring forth a multiplicity of significant scientific findings by 1990 that will assist in policy-making, it is very unlikely that all needed information could be generated by that time.

The long-term goals of the acid deposition program are to develop a number of products for policy-makers including:

- inventories and maps showing the magnitude and extent of receptors that have been affected or could be affected by acid deposition;
- estimates of the rate at which the magnitude and extent of effects or potential effects might be changing;
- "target loadings" of acid deposition for different receptors in different regions of the country;
- quantification of the contribution of local versus long-range sources to acid deposition;
- source-receptor models that can indicate which long-range sources or source regions contribute to acid deposition; and
- an operating methodology for quantifying in physical and economic terms the effects from acid deposition under future scenarios and for performing cost-benefit analyses of control and mitigation strategies.

One of the major obstacles which has delayed the scientific understanding of the acid deposition phenomenon and the formulation of control or mitigation options for acid deposition is the lack of high quality data from long-term monitoring programs and from continuously-monitored intensive research sites. The acid deposition research program has set up such monitoring networks for wet deposition. Currently, dry deposition monitoring, monitoring of lakes and streams, mountaintop cloud and forest exposure-monitoring and watershed-monitoring programs are being initiated. These efforts will be continued well into the future.

Scientific or policy developments could change the long-term direction of the research program. Some possible developments include: the scientific finding that part or all of the problem is minor; the scientific finding that part or all of the problem is getting rapidly worse or much more widespread; and/or congressional or executive action requiring emissions reduction. Such developments could bring about a considerable shift in emphasis in the research effort increasing the focus in one or more areas.

Most of the energy-research control-technology issues in this chapter focus on increased combustion of coal in an environmentally acceptable manner. These activities will continue with changing degrees of activity for individual technologies. In addition, some activity will continue to focus on new technologies needed to analyze or mitigate environmental impacts associated with the synthetic fuels.

A significant near-term issue is the determination of how current control technologies can be adapted for acid deposition applications. Technologies currently being utilized to achieve NSPS compliance are costly and have a limited capability to be used in existing facilities on a retrofit basis. If additional acid-precursor-emission reduction from existing sources is legislated, improved lower-cost technological approaches will be required. The use of the Limestone Injection Multistage Burner (LIMB) technology is one of the approaches which is being investigated.

EPA will develop information necessary to analyze or mitigate potential environmental impacts associated with the synthetic fuels industry. These impacts include air and water pollution and solid wastes disposal. All of these pollutants will be assessed and further study performed if problem areas are identified.

Pesticides and Toxics

EPA research in pesticides and toxic substances is directed toward fulfilling the current and future needs of the Agency to meet the provisions of the Toxic Substances Control Act (TSCA), the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and, to a limited extent the Federal Food, Drug, and Cosmetic Act (FFDCA). The research program discussed below will assist in the scientifically valid yet cost-effective evaluation of the risks associated with pesticides and the manufacture of new chemicals, as well as those currently in use. While several of the issues scientifically overlap with other programs, the research described here specifically relates to pesticides and toxic substances.

EPA's pesticides and toxics research will continue to evaluate health and ecological test methodologies, procedures to improve the predictability of human risk estimates, exposure monitoring systems,environmental fate and effect methods, and environmental risk assessments. Additional research will develop and evaluate release and control methods for new and existing chemicals, structure activity relationships as predictors of chemical fate and biological effects, and procedures for ensuring the human and environmental safety of the products of biotechnology. The potential for contamination of ground water discussed in the Water research chapter will be another area of interest to the ongoing pesticides and toxics research program.

Major Research Issues

Test Method Development

What new procedures or tests are needed to ensure that industry's data on environmental or health effects are accurate, reproducible and consistent?

The toxic substances and pesticides programs are unique in that under TSCA and FIFRA, EPA must provide industry with guidance to test chemicals and pesticides for potential hazards to the public health and environment.The soundness of the Agency's regulatory decisions on a chemical depends on qualitative and quantitative scientific data from industry regarding potential adverse environmental and human health effects of exposure to the chemical. Although there are a variety of test systems that could be employed to screen for potential toxicity, the sensitivity, reliability, cost and time constraints of these tests vary widely. In order to base regulatory decisions on the best

possible data, carefully screened methods are developed and approved by the Agency. These methods are incorporated into regulatory guidelines for use by industry and others who must evaluate the safety of chemicals.

ORD's health test methods research will focus on toxic hazards in five areas: reproductive effects, neurotoxicity, immunotoxicity, mutagenic or carcinogenic effects, and genetically inheritable disorders.

Research on methods for predicting environmental effects will include the evaluation of existing methods and field studies. This research will determine the sensitivity of available tests and identify species for potential future test methods development. The field tests will assist in relating present test methods to impacts observed in ecosystems. However, major advances will be required in our ability to relate single-species and generic microcosm test data to actual ecosystem effects. In addition, our understanding of comparative toxicology must be improved to adequately relate observed effects on one species to probable effects on other species.

Human Health and Exposure

What new techniques can be developed to improve the predictability of human risk from exposure to pesticides and other toxic substances?

EPA will conduct research to evaluate newly developed techniques for biological monitoring and chemical screening in epidemiology, neuro-behavioral testing, radio-immune assays and genotoxic measures of DNA damage. This includes the development of measurable indicators at the molecular level, as well as studies on metabolism to improve both dose estimates and extrapolation techniques. These biological "markers" will link chemical exposures to biological effects in an individual, and will offer a powerful tool for biochemical epidemiology. This technique will provide information on the amount of chemicals absorbed, stored, and excreted by the body, and will permit the development of dose-response relationships. Where possible, biological monitoring techniques and markers found to be promising in animal studies will be evaluated by epidemiological studies done on occupationally exposed populations.

One of the primary goals of the program is to enable quantitative extrapolations of chemical concentrations from animals to humans. This effort will include research to improve the precision of mathematical dosimetry models by providing experimental data to use as factors in the model.

Reproduction. Laboratory and clinical studies will develop methods to identify chemicals affecting reproduction. These efforts will focus on reproductive dysfunction caused by hormonal imbalance and its possible link to environmental

chemicals. In cooperation with the National Academy of Sciences/National Research Council, EPA will assess current knowledge of biological markers of reproductive dysfunction in order to develop critical hypotheses concerning the interrelationships between reproductive health, biological markers, and toxicity.

Inheritable Mutations. The sensitivity of germ cells to toxic materials potentially can affect future generations. EPA will expand its research to identify chemicals which are capable of damaging the gene structure of human chromosomes with resultant effects on fertilization, early pregnancy or implantation. This may contribute to understanding why human embryos fail to develop normally.

Certain hereditary disorders associated with chromosomal damage have been linked to chemical exposure. Rodent model systems for evaluating chemically induced gene alterations or chromosome imbalance during the fertilization cycle will be developed and evaluated. Using these techniques, efforts will be made to identify chemicals that have the potential to induce chromosomal or inheritable mutations. The genetic basis of the altered trait will be sought to allow identification of mutated sperm in the laboratory. Tests for mutations will be developed to enable the Agency to identify and evaluate the genotoxic potential of environmental chemicals and perhaps to account for the incidence of spontaneous abortions in humans.

Neurotoxicity. The development of biological indicators and tests for neurotoxicity is divided into three interrelated parts: (1) development of radio-immunoassays of proteins specific to the nervous system as potential biochemical indicators of neurotoxicity; (2) development of methods to evaluate the neurobehavioral integrity of the new-born which will include both learning capability and electrophysiological thresholds; and (3) field testing of a behavioral test battery for assessing neurobehavioral functions in human populations.

Extrapolating from High-Dose Exposure to Low-Dose Exposure. Animal toxicity testing generally is conducted at concentrations greater than the concentrations to which humans are normally exposed. This research will allow more plausible estimates of the dose-response curve at the lower concentrations. These studies will initially focus on cancer and mutagenicity. Efforts will be made to establish the relationship between incidence of cancer and mutations with the amount of a chemical or its metabolites attached to the cells' genetic material (i.e., DNA).

Epidemiology. The epidemiological research program will provide information to assist in identifying and regulating existing chemicals which may increase human health risks. EPA's research will focus on identifying potentially hazardous substances, evaluating biological measures and developing new epidemiological and biostatistical methods. These efforts will

provide sensitive measures of adverse effects to organ systems as well as a means of evaluating proposed risk-assessment models.

Existing records will be evaluated to identify occupational and demographic groups which appear to be at increased risk of birth defects, cancers and other environmentally related disorders. Subsequent studies will determine if specific chemicals may be responsible for observed increases in disease rates. Epidemiological comparisons of traditional exposure and response measures to newly developed biological methods will also be implemented. Risk estimates extrapolated from animal models will be compared to observed hazard levels in appropriate human populations.

Exposure Monitoring

What monitoring methods are needed to provide information to estimate human exposures?

Methodologies for measuring human exposure to environmental pollution continue to evolve. Most of the Agency's previous monitoring efforts have focused on data collection to document ambient conditions for enforcement purposes or on conducting laboratory toxicological tests to determine human health effects. In the past few years, however, some progress has been made in determining the actual exposures of humans to environmental pollutants. A modest exposure monitoring program has been initiated, and methods development research has become more sophisticated.

The objective of the exposure monitoring research program is to develop the appropriate methodologies. This includes personal monitoring instrumentation, analytical methods, population sampling schemes, questionnaires and diaries, exposure models, activity pattern data bases, quality assurance procedures, and pilot field studies to determine, with known accuracy, the distribution of the population's exposures to environmental pollutants of concern to the Agency.

The data generated by these methodologies can be used to improve both the quality of public health risk estimates and the meaningfulness of conventional data collected by existing monitoring networks. The resulting exposure data also can be used to develop and validate exposure models which allow the Agency to evaluate the impact on exposures of alternative regulatory strategies and national standards.

The Total Exposure Assessment Methodology (TEAM) approach includes data collected on the exposures of a population to all environmental media (air, drinking water, food), including estimates of "body burden" as measured in blood, urine, and breath. TEAM methodology uses a respresentative random sample of the population, stratified to reflect important attributes with respect to pollutant exposure, that makes it possible to extrapolate the findings to the much larger popu-

lation of a city or a region. Since 1979 TEAM studies have successfully demonstrated the use of personal monitors to measure the air exposures of people to over 50 organic compounds with particular emphasis on about 20 target compounds, including several important carcinogens. In the future the TEAM methodology will be adapted to other chemicals by undertaking field studies to determine the exposure of the general population to a variety of chemicals.

Planning also is underway for a long-range field monitoring program that seeks to consolidate the Agency's exposure monitoring research capability and expertise into one metropolitan area, called a Human Exposure Assessment Location (HEAL). This program is international in scope, with each of several participating nations designating its own HEAL study area and funding its own exposure monitoring field programs in that area. In each HEAL, similar statistical designs and measurement methodologies would be applied, thus permitting the findings from different countries to be compared. Coordination of this program is being supplied by the World Health Organization in Geneva, and each HEAL will be designed to meet the sponsoring nation's most critical exposure monitoring research need. By pooling scientific resources from several nations, the HEAL's program has the potential for significantly advancing our understanding of the actual exposures of the population to toxic chemicals, thereby increasing the meaningfulness of data from existing monitoring programs and improving the quality of estimates of the risk of these pollutants to public health.

The Exposure Monitoring Test Site (EMTS) is being established to provide opportunities for exposure methods testing (testing the methods and instrumentation) at a well-characterized geographical location. Use of a single site is economical and provides for important background information regarding industrialization, routine environmental and public health monitoring, demography, and geography to be considered in methods evaluation. In 1984 the site criteria were defined and several candidate sites selected for consideration. In 1985 a candidate will be selected and verified as being suitable for use as the EMTS. Efforts to conduct projects at the site will begin after the characterization process.

Research is being conducted to develop a quantitative analytical method to detect azo dyes in environmental media. This method will be used to determine how well industrial and municipal water treatment systems deal with these dyes and whether or not there is human and environmental exposure. In 1984 analytical methods were evalauted. Modifications in extraction procedures will be made in 1985 to improve these methods. Concurrently, joint efforts will be made to provide analytical support to environmental engineers using these dyes to evalaute the efficacy of water treatment systems to deal with these chemicals. This cooperative research may be expanded to research for other chemicals in 1986.

Environmental Fates and Effects

What new laboratory capabilities must be developed and validated to assess the environmental effects or risks from toxic chemicals?

Ecosystems are composed of multiple populations which differ throughout the continental U.S., making it difficult to establish protocols for well-defined environmental risk assessments. While health risk assessments are targeted to human populations, environmental risk assessments have no single, definitive populations upon which to focus. Moreover, if the populations at risk are identifiable, there may not always be applicable toxicity data for those particular species. Instead of obtaining toxicity data on the exact populations at risk, toxicity data from surrogate laboratory or test populations are used. In such cases, uncertainty may arise over the applicability of data from the surrogate populations.

To determine whether ecologically or commercially important organisms are in jeopardy from new chemicals in the environment, basic information must be provided on chemical transport, transformation, habitat alteration and biological effects. EPA's research is directed toward predicting levels of exposure by determining where new chemicals may exist in the environment and describing their movement through air, soils, sediments, fresh and estuarine surface waters and ground water. Thus, the program must determine potential pollutant distributions in ecosystems, the relevant ecological, physical, chemical and biological processes and ascertain the physical, chemical and biological parameters which affect chemical fate. Field studies in experimental and natural ecosystems will provide the necessary data for further model development as well as the verification of existing hazard assessment techniques.

Studies to improve the reliability of models to predict environmental concentrations of pesticides or toxic substances will be conducted through development of mathematical descriptions of phenomena, such as sorption onto particulate matter, followed by validation through a program of field testing and laboratory studies. Analyses of mathematical models will further determine the sensitivity of model outputs to environmental parameters.

Field tests of some fate and exposure models have been conducted, and additional field verifications will be initiated. In partial support of the biological effects needs, ecological effects testing approaches must be improved and field-tested. Small-scale controlled environments of sufficient reliability for regulatory evaluations, e.g., microcosms, are also being studied. Fate and effects microcosm research will include scaling and model fitting; using specific types of microcosms to evaluate risk-assessment processes; and evaluating specific microcosms to assess conditions in varied geographical situations.

The present course of improvement and application of mathematical models will emphasize precision, incorporation of new field data when available and use of improved theory where applicable. Exposure models and hazard assessment techniques will be developed or modified for a range of aquatic and terrestrial situations to yield an estimate of environmental risk.

Chemical Release and Controls

What engineering and technological information is needed to identify the release of and exposure to toxic substances and to determine alternatives for control of these substances?

Under the premanufacture notification process, the manufacturers of new chemicals or proposers of significant new uses of existing chemicals are required to submit information to EPA for prior review. EPA uses existing data to predict the risks of and from the release of new substances, and, under the existing chemicals control program, evaluates technological alternatives to reduce the release of and exposure to chemicals that are already in use.

Predictive Capabilities. Models to predict the release of and exposure to different classes of new chemicals will be developed to assess different chemical-unit operations and processes, the physical and chemical properties of chemicals, to predict the potential exposure and release levels, and the best control measures to control release and exposure of new chemicals. Pilot-scale testing for the treatability of classes of potentially toxic chemicals will be conducted to validate these predictive models.

Control Alternatives. Alternatives to mitigate the release of and exposure to specific existing and new pesticides and toxic substances will be defined through the evaluation and adaptation of control measures related to the release in the workplace and into the environment of the chemicals. Technologies, management practices, and personal protective equipment to limit the release into the environment and exposure of pesticide applicators will be evaluated.

Structure-Activity Relationships

What additional information and techniques are required to estimate the environmental behavior of new chemicals through their chemical or physical similarities to known compounds?

EPA's Office of Toxic Substances evaluates human and environmental risks associated with the introduction of new chemicals under TSCA. Since little, if any, relevant toxicity information is submitted for new TSCA chemicals under development, decisions regarding their potential health and environmental risk must rely heavily on existing knowledge

about similar chemicals and on estimations of physical and chemical properties. The use of structure-activity relationships (SAR) is a promising technique to estimate the environmental toxicity and behavior of a new substance based upon its chemical or structural similarities to other known compounds.

SAR has been applied with some success in the pharmaceutical industry where interactions with very specific biological receptors are necessary, although application of this technique to predict the broad range of potential health effects resulting from exposure to chemicals with diverse properties is limited. EPA will investigate the use of structure-activity relationships in estimating health effects in the areas of systemic toxicity and genetic activity. A SAR method using molecular-electrostatic-interaction-potential as a premanufacture screen for predicting chemical toxicity is also being evaluated as a possible regulatory tool.

To enhance the Agency's ability to utilize SAR, SAR health effects data bases will be expanded by conducting bioassay studies on a series of structurally related chemicals which represent chemical classes frequently encountered by EPA's new-product evaluators. This approach may allow the development of SAR methods specifically tailored for the types of chemicals EPA might be regulating in the future. Thus, methods for predicting toxicological effects of chemicals based on a variety of physiochemical parameters may be developed, including their transport, metabolism, ability to bind to critical cellular macromolecules and DNA-repair characteristics. Additionally, work will be continued to relate the genetic activity of specific compounds (and/or classes) to chemical structure.

The health risk assessment research program will emphasize three aspects: determination of qualitative effect and quantitative dose response data on specific, high-concern compounds and chemical classes; development of systematic procedures, beginning with genetic toxicity, for integrating individual toxicological test results and SAR predictions into an overall risk estimate; and expansion of quantitative animal test data into human disease-susceptibility models.

SAR research is also developing correlations for predicting the environmental toxicity of new chemicals to freshwater, marine estuarine and terrestrial species, as well as for predicting the behavior and fate of toxic chemicals in the environment. Considerable progress has been made in predicting the chemical and physical properties of chemicals. Future chemical fate estimation techniques will emphasize the prediction of rates of transport (e.g., volatilization from water) and rates of transformation (e.g., sunlight photolysis and biodegradation), and rates of uptake of chemicals into living organisms. Environmental effects tests will continue to develop estimation techniques for predicting the potential for narcosis, cholinesterase inhibition and respiratory uncoupling, which appear to be major toxicity mechanisms in animals.

Biotechnology

What methods and technologies are needed to ensure human and environmental safety from microbial agents and products of biotechnology?

Data, methods and models are required for EPA to assess the public health and environmental risks associated with biotechnology products. Many steps in assessing risks of genetically engineered organisms are similar to those used to assess the risks of chemical substances. However, additional complexities are encountered because of the potential for organisms to grow, infect, transform, spread and exchange genetic information resulting in the potential acquisition of pathogenic traits. These engineered organisms may also have the capability of outcompeting and thus replacing natural organisms. EPA's research efforts in biotechnology constitute a comprehensive effort to deal with the potential problems posed by the release of bioengineered products into the environment.

In the monitoring research program, efforts will be directed to develop capabilities to identify and monitor genetically engineered organisms, their products, and their genetic material in the environment. This research will result in a manual for use by EPA and others engaged in environmental monitoring to assure data quality. Identification of gaps in methods for monitoring and requirements and validation limits for quality assurance will be addressed.

Environmental processes and effects research will determine the survival and fate of genetically engineered organisms released into the environment and assess their potential impacts. Short-term needs for this area will include the development of specific, sensitive methods to identify and track genetically engineered organisms in the environment, and rapid qualitative and quantitative screening of fate and effect techniques. Long-term studies will assist in understanding and predicting the impact, exposure, hazard, and environmental risk of genetically engineered organisms in the environment.

Health research efforts will develop predictive *in vivo* and *in vitro* tests for adverse health effects to human populations. This research will assess the application of guidelines for microbial pesticides to general use in testing genetically engineered organisms for adverse health effects. Also, this effort will identify additional sources of available test methods, assess their applicability for EPA use and incorporate them into a data base.

Engineering and control technology efforts will improve containment, control and destruction measures and produce alternative engineering methods which may be used for the containment and destruction of organisms, containment in field tests, and reducing worker exposure.

Assessments of environmental risk will incorporate data from monitoring, environmental impact and health effects studies

into effective, predictive assessments of potential harm to human health or the environment. Initial emphases in this area will be towards the preparation of guidelines for developing test methods, assessing data and evaluating test results on potential hazards of biotechnology. Further, biotechnology exposure guidelines will be developed to assess potential hazards resulting from exposure to genetically altered organisms. Workshops will also be held in relevant disciplines of biotechnology such as the environmental aspects of genetically engineered microbial and viral systems. Recommendations from these workshops, combined with expert panels and relevant research, should provide a sound background for biotechnology guidelines.

Summary of Long-Term Trends

The toxics and pesticides research program focuses primarily on the intentional or unintentional release of new and/or existing chemicals into the environment. To protect human health and the environment adequately from unreasonable risks, a wide array of research issues must be addressed to support the regulatory needs. Each of the research issues which has been discussed within this chapter will continue into the next decade, with varying degrees of emphasis.

Test methods development will continue at a relatively level pace to provide methods to measure chemicals in the environment and determine their hazard. As currently available methods are standardized, efforts will continue to develop and evaluate new sensitive yet cost-effective techniques for potential use in test guidelines. In the health area these new methods will involve greater reliance on endpoints other than carcinogenicity and thus will be an area of increased activity. By utilizing these new techniques, the health assessment activities will be better able to provide the data necessary to conduct quantitative risk assessments. To this end, research will increase on extrapolating from effects at high to low doses and from animals to man. This will reduce the level of uncertainty associated with the use of laboratory data in predictions of human health risk. The development and increased use of biological markers also will assist in this area by providing a more accurate measure of actual human exposure levels. These techniques may provide new tools for epidemiological studies. In conjunction with these studies, the development of exposure monitoring systems will initially increase with subsequent leveling off as improvements are made in monitoring methods, systems, and analyses.

While these studies relate primarily to human risk assessments, a relatively new area is environmental risk assessment. Ecological hazard assessment methods will continue to be developed to determine the environmental fate and effects of chemicals. This effort will culminate in the development of ecological hazard models. While effects and exposure methods will provide

information to evaluate risk, developing more definitive techniques for conducting environmental risk assessments will undoubtedly be a long-term process.

As the list of new chemicals continues to grow, research to provide information on the release and control of these chemicals will allow the rapid and accurate prediction of how much and where chemicals will be released into the environment, and with increasing accuracy, an estimation of their environmental effects.

To address the expected growth of genetic engineering, EPA will provide methods to protect public health and the environment from the potential adverse impacts of microbial agents and the products of biotechnology. EPA's research will help to determine containment facilities for bioengineered organisms and means of monitoring the survival and distribution of those intended for release. The initial emphasis will be on developing methods to assess survivability and ecological effects.

The structure-activity research program will continue as the methods for predicting fate and effects of parent and degradation compounds become more available.

Exploratory Research Program

Solutions to environmentally related problems often require a more basic or fundamental understanding. A primary goal, therefore, of the Office of Research and Development is to develop new knowledge and principles that can be used to address and resolve environmental problems. ORD is particularly interested in long-range strategic research issues addressing emerging environmental problems. Consequently, in addition to the research conducted through the laboratories, ORD supports exploratory research through its research grants and centers programs.

Exploratory Grants Program

The research grants program is designed to elicit investigator initiated proposals to meet the following Agency objectives: improve the quality of science and scientific information in areas important to the Agency's programs and mission; stimulate investigation of emerging environmental problems and identify steps which can predict their occurrence; enrich basic research with long-range objectives to provide extended direction to the scientific program of EPA; expand the innovative and creative base of the mission-oriented research which makes up the bulk of the EPA research programs; and bring new investigators into environmentally-related research areas.

The competitive peer review research grants program was initiated in 1980 through an annual national solicitation designed to highlight specific areas of inquiry. Although all valid proposals are considered, the solicitation typically emphasizes research needs in five areas: environmental health; environmental biology; environmental engineering; chemistry and physics in air; and chemistry and physics in soils and water.

The grants selection process combines the most successful features of the dual review systems used by the National Science Foundation and the National Institutes of Health. *Ad hoc* panels, chaired by scientists or engineers from outside EPA, meet at least twice annually to discuss reviews of each proposal conducted by at least three experts in the relevant field. Applications that pass the scientific panel review are then reviewed by Agency personnel for their relevancy in meeting Agency needs. The combined dual-review recommendations are rank-ordered and the grants are awarded based upon the availability of funds.

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The grants program uses those issues identified by the five research committees as guidance in determining priority research needs. Exploratory research focuses on projects which might provide information or solutions in the long term. The specific projects which may be supported by this program, however, depend upon the proposals submitted in response to the solicitations. Thus, while the basic issues addressed will be similar to those described in previous chapters, the actual nature of the research undertaken cannot be predicted.

Environmental Health. The environmental health research program looks at the identification, assessment, control and management of risks to health from anthropogenic and natural alterations of the environment. Factors to be studied will include: principle modes of transmission; critical modes of exposure factors governing susceptibility and resistance; categories of biologic response, methods for detecting exposure, early biological responses and the consequences of long-term exposure; relationship of acute to chronic toxicity; modes of biologic prevention and treatment; and isolation, elimination, or dissemination of agents.

Air Research. The air research panel is concerned with the study of the sources, transport, transformation and fate of air pollutants. The program is concerned with applications providing time-space patterns of pollutant concentrations, detailed chemical and physical descriptions of pollutants, mathematical models connecting air pollutants with probable sources, and procedures for investigating the impact of pollutants on human health, the environment, visibility, climate and materials. It draws heavily upon the concepts and procedures of physics, chemistry and meteorology using models and measurement methods to develop quantitative description of these phenomena.

Environmental Biology Research. The environmental biology effects research panel receives applications on the study of effects of pollutants and pollution abatement practices on biota and on ecosystems of varying complexity and spatial extent. A major objective of this program is to provide information that, in combination with exposure data, allows the prediction of the environmental risk of pollution on individual organisms and on ecosystems. The risks include the reduction of productivity in agricultural areas, wetlands, and freshwater and coastal marine ecosystems as well as human exposure to toxic substances through accumulation in the food chain. This research area also includes studies on biotechnology.

Aquatic and Soils Research. The major objective of this research is to provide the basis for predicting the time-space patterns of pollutant concentrations in aquatic and soil systems. This ability to predict concentration patterns is important in exposure assessments and in determining the capacity of the environment to assimilate pollution. The research also frequently provides possible approaches to treatment of wastes

and management practices to minimize the environmental impact of waste sources. The research is broadly based on the concepts and techniques of physics, chemistry and microbiology. It includes small-scale laboratory studies and large-scale field projects relating to the transport and transformation of pollutants in the aquatic and soil environments.

Environmental Engineering Research. The environmental engineering research program emphasizes new, innovative pollution control and waste management techniques in air, water, and soils. These include source monitoring characterization, cost-effective production process modification, pollutant emission abatement, residuals control, and mitigation of acid rain. While hazardous wastes will receive particular attention in future solicitations, research on air, wastewater, and toxics control technologies and drinking water and multimedia technologies will be supported.

Exploratory Research Centers

The exploratory research centers program is designed to achieve four major objectives: address long-term exploratory research needs of importance to EPA's mission that require multi-media and multi-disciplinary approaches; promote and maintain a critical research mass by providing stable and continuing funding; extend the capabilities of EPA's laboratories; and establish links between EPA and the scientific and technical communities.

There are now eight centers, seven of which were the subject of a national competition. The proposals received were peer-reviewed for scientific and technical merit and reviewed by Agency personnel to ensure they supported Agency needs. All centers are funded through cooperative agreements which allow interactive design and implementation of research programs of mutual interest. In general, each center began its operation by conducting a series of assessments of the high-priority research needs that subsequently formed the basis of their activities.

Advanced Environmental Control Technology Research Center (University of Illinois). The objective of this center is to increase scientific knowledge of the chemical, physical and biological principles underlying the technologies used to control air and water pollution. Emphasis is placed on technologies which are innovative or not yet commercially available and which will develop faster with additional scientific research or improved dissemination of technical information.

Industrial Waste Elimination Research Center (Illinois Institute of Technology and Notre Dame University). The mission of this center is to reduce or eliminate industrial pollutant discharges through innovations in industrial processes and development of recycle/recovery strategies. Rather than focusing on "end-of-

pipe" controls, the center emphasizes research on in-plant controls that include methods for recycling, recovery, and reuse of by-products of industrial processes; modifications of manufacturing processes to avoid or reduce generation of wastes; and developing "clean" manufacturing technologies that minimize or eliminate the generation of pollutants.

Hazardous Waste Research Center (Louisiana State University). The focus of this research center is the development of advanced technologies for the destruction, detoxification, recovery or containment of hazardous wastes including incineration, alternate methods of treatment, and waste/ materials interaction.

National Center for Intermedia Transport Research (University of California-Los Angeles). This center studies the important physical and chemical processes associated with the transport of particle or gaseous environmental pollutants from one medium—the atmosphere, land and water—to another. Key problems being addressed include determining the organic and inorganic chemicals that are deposited as a result of dry and wet fallout; the influence of temperature, humidity, vegetation growth, and other factors on the pollutant condensing process; the transport mechanisms of chemicals placed on land by man into the atmosphere; the mechanisms of action which control the exchange of pollutants between the land, atmosphere, and large bodies of water; and the accumulation of previously unidentified new chemicals in the atmosphere.

National Center for Groundwater Research (Rice University, University of Oklahoma and Oklahoma State University). The objective of groundwater research at the center is to improve the understanding of the subsurface environment and its interaction with pollutants. Directly or indirectly, groundwater is the major source of the Nation's drinking water, but it may be contaminated with pollutants from a wide variety of sources. Efforts to mitigate this contamination are complicated by the extremely slow movement of pollutants underground. Priority research issues include transport and fate processes; study of subsurface and pollutant characteristics which play a key role in those processes; and development of methods to assess and protect groundwater quality.

Ecosystems Research Center (Cornell University). The primary objectives of the center are to identify fundamental scientific principles and concepts of ecosystems and determine their importance in understanding and predicting the responses of ecosystems to stress; to describe basic mechanisms that operate within ecosystems and the stability of ecosystems stressed by pollutants; and to evaluate the applicability of those theoretical concepts to problems of concern to EPA including retrospective and other case studies. The center will conduct studies of particular ecosystems to characterize ecosystem responses to stress, comparative studies to classify the responses of different ecosystems to a variety of stresses and make recommendations

for appropriate ecotoxicology methods and studies to test the applicability of ecosystem concepts to problems of special concern to the EPA.

Center for Environmental Epidemiology (University of Pittsburgh). The primary objective of this center is to improve the understanding of the human health risks associated with environmental pollution, especially chronic disease epidemiology. The priorities for the center include problem definition and feasibility assessments for epidemiology studies, development and improvement of epidemiological methods related to environmental health, research on exposure assessment relevant to epidemiological investigations, and support to EPA on epidemiological studies. Five task groups have been established to identify research needs and priorities in airborne particulates, indoor exposure to hazardous materials, drinking water and wastewater, cardiovascular diseases, and methods for evaluating exposure and health endpoints.

Marine Sciences Research Center (University of Rhode Island). The objective of this center is to develop methods for predicting the behavior of estuarine systems. The center provides fourteen large-scale (3,500 gallons each) simulations of estuarine systems to test ecosystem effects of pollutant discharges. Emphasis is on ecosystem-level studies of the behavior and effects of selected pollutants associated with natural and introduced particulates, including the dispersive behavior and effects of low-level radioactive soils disposed in marine waters.

Appendix A: Resource Options

The law requiring the submission of this research strategy document to Congress is Section 5 of Public Law 94-475. The same law also requires that a five-year projection be provided indicating the potential research response to different resource levels.

The following section on resource options includes, as required by law, descriptions of conditions for high, moderate, and no growth. The growth rates associated with these options are zero for no growth, three percent for moderate growth and six percent for high growth. No additional resources are required or expected as a result of this submission. Rather, these growth scenarios are intended, as required by the law, to indicate potential program increases in EPA's research and development.

Water

1985 Current Estimate $52.0 Million
1986 President's Budget $52.1

Growth	Projections 1987	1988	1989	1990
None	52.1	52.1	52.1	52.1
Moderate	53.6	55.3	57.0	58.7
High	55.3	58.6	62.1	65.8

No Growth: The program will proceed as described in this Agenda.

Moderate: Efforts to develop a greater understanding of the transport and fate of pollutants in groundwater will be accelerated. Additional efforts will be made to determine the potential health effects of those substances found in drinking water.

High: The additional efforts cited under the moderate growth option above will be augmented and accelerated.

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Air and Radiation

1985 Current Estimate $69.2 Million
1986 President's Budget $65.6

Growth	Projections 1987	1988	1989	1990
None	65.6	65.6	65.6	65.6
Moderate	67.6	69.6	71.7	73.8
High	69.6	73.7	78.1	82.8

No Growth: The program will proceed as described in this Agenda.

Moderate: Additional work will be directed toward the improvement of health effects information; particularly in the area of the development of models to permit the extrapolation from high dose to low dose, and animals to man.

High: Additional efforts will improve the characterization of ambient atmospheres with emphasis on potential hazardous air pollutants. Source characterization and mitigation will be expanded for specific industries.

Hazardous Wastes

1985 Current Estimate $40.9 Million
1986 President's Budget $49.6

Growth	Projections 1987	1988	1989	1990
None	49.6	49.6	49.6	49.6
Moderate	51.0	52.6	54.2	55.8
High	52.5	55.7	59.0	62.6

No Growth: The program will proceed as described in this Agenda.

Moderate: Additional efforts will investigate alternate disposal/destruction technologies to provide disposal capacity for wastes banned from land disposal.

High: Additional effort will be invested in the development of advanced alternative disposal/destruction technologies. Techniques to detect and monitor subsurface movement of hazardous waste leachate will be further investigated.

Multimedia Energy

1985 Current Estimate $58.1 Million
1986 President's Budget $67.2

Growth	Projections 1987	1988	1989	1990
None	67.2	67.2	67.2	67.2
Moderate	69.2	71.3	73.4	75.6
High	71.2	75.5	80.0	84.8

No Growth: The program will proceed as described in this Agenda.

Moderate: Additional efforts will be made to accelerate acid deposition research to identify cause/effects mechanisms of forest changes. Evaluations and assessments of a variety of utility boiler control technologies will be expanded.

High: Additional efforts will be made to understand the linkages between terrestrial and aquatic ecosystems as they relate to acid deposition impacts. Research on utility boiler controls will be accelerated.

Pesticides and Toxics

1985 Current Estimate $36.2 Million
1986 President's Budget $50.0

Growth	Projections 1987	1988	1989	1990
None	50.0	50.0	50.0	50.0
Moderate	51.5	53.1	54.7	56.3
High	53.0	56.2	59.6	63.1

No Growth: The program will proceed as described in this Agenda.

Moderate: Additional efforts will be devoted to accelerating research in ecotoxicity, structure-activity relationships and issues related to biotechnology.

High: The efforts described under moderate growth above will be augmented and accelerated.

Exploratory Research

1985 Current Estimate $21.2 Million
1986 President's Budget $13.9

Growth	Projections 1987	1988	1989	1990
None	13.9	13.9	13.9	13.9
Moderate	14.3	14.7	15.2	15.6
High	14.7	15.6	16.5	17.5

No Growth: The program will proceed as described in this Agenda.

Moderate: Additional efforts in the grant program will be devoted to environmental health and biology. Increases in the centers program will be equally divided among existing centers.

High: Additional increases as indicated under moderate growth.

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